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USAAVLABS TECHNICAL REPORT 64-68M

HEAVY-LIFT TIP TURBOJET ROTOR SYSTEM
VOLUME XIII

PRELIMINARY
MODEL SPECIFICATION
FOR
CONTINENTAL MODEL 357-1 ENGINE

October 1965

U. S. ARMY AVIATION MATERIEL LABORATORIES

FORT EUSTIS, VIRGINIA

CONTRACT DA 44-177-AMC-25(T)

HILLER AIRCRAFT COMPANY, INC.

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USAAVLABS Technical Report 64-68M
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VOLUME XIII

PRELIMINARY MODEL SPECIFICATION FOR CONTINENTAL MODEL 357-1 ENGINE

Prepared For
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for

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

(U.S. Army Transportation Research Command when report prepared)

CONTENTS

ILLUSTRATIONS

Specification No. 2253-A

PRELIMINARY
MODEL SPECIFICATION *

ENGINE, TURBOJET, HELICOPTER ROTOR–TIP MOUNTED

CONTINENTAL AVIATION AND ENGINEERING CORPORATION
CONTINENTAL MODEL 357-1

1. SCOPE

1.1 Scope. - This specifications cover the requirements of the CAE Model 357-1 turbojet engine for helicopter rotor tip applications.

1.2 Classification. - The CAE Model 357-1 has an annular ram air inlet; a single-stage transonic axial compressor, a single-stage centrifugal compressor, a straight-through flow annular combustion chamber; a single-stage axial flow turbine; and a plug nozzle type exhaust.

The engine is designed as a simple cycle, rugged, lightweight, engine intended for helicopter rotor tip mounted operation.

2. APPLICABLE DOCUMENTS

2.1 Specifications. - The following specifications form a part of this specification except as modified herein:

MIL-E-5007B	Engines, Aircraft, Turbojet, General Specifications for:
MIL-E-5009B	Engines, Aircraft, Turbojet, Qualification Tests for:
MIL-E-5010B	Engines, Aircraft, Turbojet, Acceptance Tests for:

*Format complies with Military Specification MIL-E-5008B, "Engines, Aircraft, Turbojet, Model Specification For (Outline and Instructions for Preparation)".

‾.2 Publications. - The following publications shall be applicable to this specification except as specified herein:

ANA Bulletin 343p	Specifications and Standards Applicable to Aircraft Engines Use of:
ANA Bulletin 438a	Age Control of Synthetic Rubber Parts

3. REQUIREMENTS

3.1 Model Specification. - This specification conforms to Specification MIL-E-5008B in basic format. Deviations, and/or additional requirements due to the extreme force field existing at the normal operating conditions, are defined under similar or appropriate paragraph headings and numbers.

3.4 Performance Characteristics. - The engine performance ratings and estimated performance characteristics are based upon the use of fuel having a lower heating value of 18,400 B.t.u./lb. and otherwise conforming to Specification MIL-J-5161, Grade 1; and oil conforming to Specification MIL-L-7808. These data indicate performance attainable under standard or specified conditions, with no air being bled from the compressor, with the power control system specified herein, and with the optimum jet nozzle as furnished with the engine.

3.4.1 Fuel. - The engine shall function satisfactorily throughout its operation range for any steady-state and transient operating condition when using fuel conforming to Specification MIL-J-5624, Grade JP-4.

3.4.1.1 Alternate Fuel. - The engine shall function satisfactorily throughout its complete operating range when operated with fuel conforming to Specification MIL-J-5624, Grade JP-5.

3.4.1.2 Emergency Fuel. - The requirements of this paragraph shall apply except that fuels conforming to Specification MIL-G-5572 shall not be limited to Grade 115/145.

3.4.1.3 Fuel Contamination. - The engine shall function satisfactorily when using fuel contaminated to the extent specified below:

Contaminant	Particle Size	Quantity
Iron Oxide Iron Oxide	0-5 Microns 5-10 Microns	28.5 gm/1000 gal. 1.5 gm/1000 gal.
Sharp Silica Sand Sharp Silica Sand	40-50 Mesh 50-100 Mesh	1.0 gm/1000 gal. 1.0 gm/1000 gal.
Prepared Dirt Conforming to AC Spark Plug Company, Part No. 1543637. (Coarse Arizona Load Dust)	Mixture as follows: Microns — Percent 0-5 — 12 5-10 — 12 10-20 — 14 20-40 — 23 40-80 — 30 80-200 — 9	8.0 gm/1000 gal.
Cotton Linters	Grade 6, Staple below 7; second cut linters. (Per U.S. Department of Agriculture Standards)	0.1 gm/1000 gal.
Crude Naphthenic Acid		0.03 percent by volume
Salt water in accordance with salt spray solution per MIL-E-5272, except using a 4 percent salt concentration		0.01 percent entrained

3.4.3 Oil Consumption. - The oil consumption shall not exceed the following:

1.0 lb./hr. at Military rated thrust or below

The estimated maximum oil consumption during average service usage is 0.8 pounds per hour.

3.4.4 Ratings. - The performance ratings shall be as listed in Tables 1, 1A, and 2. These data indicate performance under standard conditions, with no air being bled from the compressor, and using an optimum jet nozzle area.

TABLE 1
PERFORMANCE RATINGS
STANDARD SEA LEVEL STATIC CONDITIONS

Rating	Net Jet Thrust-Pounds (Min.)	Engine Rotor Speed (Max.) r.p.m.	Engine Rotor Speed (Max.) %	Specific Fuel Consump. lb/hr/lb.-thrust (Max.)	Measured Gas Temp. (Max.) °F.	Measured Gas Temp. (Max.) °C.	Airflow ± 3% lb/sec.
Military	1700	22,000	100.0	0.99	1300	704	28.2
Normal	1375	20,790	94.5	0.98	1150	622	26.9
90% Normal	1225	20,130	91.5	0.99	1080	583	25.3
75% Normal	1025	19,140	87.0	1.03	1030	555	24.2
Idle	130*	9,500/	43.2	420**	1240*	671*	-

NOTE: It shall be permissible to increase speed at the 90 percent and 75 percent ratings to meet specified thrust guarantees providing that, at the increased speed necessary, the specified specific fuel consumption is not exceeded.

* Estimated ** lb/hr.

TABLE 1-A
PERFORMANCE RATINGS
STANDARD SEA LEVEL HOVER CONDITION - V_T = 650 ft/sec.

Rating	Net Jet Thrust-Pounds (Min.)	Engine Rotor Speed (Max.) r.p.m.	Engine Rotor Speed (Max.) %	Specific Fuel Consump. lb/hr/lb.-thrust (Max.)	Measured Gas Temp. (Max.) °F.	Measured Gas Temp. (Max.) °C.	Airflow ± 3% lb/sec.
Military	1540	22,000	100.0	1.29	1300	704	33.1
Normal	1165	20,790	94.5	1.32	1150	622	30.0

TABLE 2
PERFORMANCE RATINGS
6000 FT. ALTITUDE, 95°F DAY, HOVER CONDITION*

Rating	Net Jet Thrust-Pounds (Min.)	Engine Rotor Speed (Max.) r.p.m.	Engine Rotor Speed (Max.) %	Specific Fuel Consump. lb/hr/lb.-thrust (Max.)	Measured Gas Temp. (Max.) °F.	Measured Gas Temp. (Max.) °C.	Airflow ± 3% lb/sec.
Military	1070	22,000	100.0	1.30	1310	708	24.0
Normal	880	20,790	94.5	1.295	1160	626	23.0

* Rotor Tip Speed, V_T = 650 ft./sec.

3.4.5. Estimates. - Estimated performance curves, Figures 1 through 4, shall constitute a part of this specification. These data indicate performance predicated upon: no inlet duct losses, no air being bled from the compressor, operation based upon the minus tolerance of the power control system, operation at standard or specified conditions, and use of an optimum jet nozzle area.

3.4.5.1 Corrections. - Minimum corrections are presented in Figures 5 through 16. Corrections applicable to the operating conditions will be presented in a subsequent revision of this specification.

3.4.6 Altitude - Temperature Limits. - The estimated engine operation and starting limits are shown in Figures 17 and 18.

3.4.6.1 Sea Level Operating Limits. - The engine shall function satisfactorily up to and including a ram pressure ratio of 1.78 at standard sea level conditions, at -65°F (-54°C.) ambient temperature, and at +115°F. (+46° C.) ambient temperature.

3.4.6.2 Flight Starting Limits. - The estimated flight starting limits are shown in Figure 18.

3.4.6.4 Absolute Altitude. - The absolute altitude of the installed engine shall not be less than 25,000 feet at a ram pressure ratio of 1.7.

3.4.7 Flight Conditions. - Flight condition requirements conventionally outlined as MIL-E-5007B do not represent applicability to a turbojet engine used as a helicopter rotor tip mounted propulsive device. In lieu thereof the following shall apply: "The engine shall operate satisfactorily during all flight conditions encountered during helicopter operation wherein the engine is rotor tip mounted and subjected to the flight maneuver forces specified in paragraph 3.14 and Table 3."

3.4.9 Idle. - The idle position on the ground as set by the power lever idle position shall be 9500 r.p.m. $\pm$ 1000 r.p.m. No provisions for ground reduction shall be made. The idle thrust shall not exceed 10 percent of the maximum thrust from sea level to 6000 feet altitude.

3.4.10 Reverse Thrust. - No provisions for reverse thrust shall be made.

3.4.11 Thrust Transients. - The provisions of this paragraph shall apply to the transients listed below. The values shown shall be applicable for operating conditions during which the engine inlet air velocity is 650 feet per second.

a. From idle condition to military thrust available 9 seconds, from sea level to 6000 feet.

b. From 30 percent military to military thrust available, 5 seconds, from sea level to 6000 feet.

c. From idle condition to military thrust available 12 seconds, from 6000 feet to the absolute altitude.

d. From military thrust condition to idle thrust, 5 seconds from sea level to 6000 feet.

3.4.12 Stability. - The requirements of this paragraph shall apply while hovering in still air conditions. The over-all stability requirements compatible with conditions of forward flight will be defined in a subsequent revision of this specification.

3.4.13 Rate of Pressure and Temperature Change. - The requirements of this paragraph shall not apply.

3.4.15 Measured Gas Temperature. - The maximum allowable measured gas temperatures shall be as follows:

Condition	Temperature °F.	°C.
Military	1330	722
Normal Rated and Below	1180	638
Starting (1,500 - 11,000 r.p.m.)	1450	788

The maximum allowable measured transient gas temperature shall not exceed 1375°F.(746°C.) for more than 3 seconds at engine speeds greater than 11,000 r.p.m. In no case shall the measured transient gas temperature exceed 1600°F. (872°C.).

3.4.15.1 Measurement. - The exhaust gas temperature measurement device shall consist of 5 chromel-alumel type thermocouples arranged to detect representative exhaust gas temperatures. The thermocouples shall be so wired to present an average temperature signal. The EMF output of the thermocouples used shall conform with the values given in National Bureau of Standards Circular No. 561. The cockpit indicating instrument shall be required to accept a signal range from 0°F. to 1800°F. (-18°C. to 982°C.).

3.4.16 Starting. -

3.4.16.1 Engine Starting. - The engine shall consistently be capable of satisfactory ground and air starts within the limits established in Figures 17 and 18. Satisfactory starts shall be made within the time limits shown in Figure 1 of Specification MIL-E-5007B when using a starting system compatible with the requirements shown in Figure 19.

3.4.16.2 Starting Torque and Speed Requirements. - The starting torque and speed requirements are shown in Figure 19.

3.4.16.3 Restart Time. - The minimum allowable time between ground starting attempts, as determined by engine system limitations, shall be 30 seconds. Starts may be attempted following a 10 second purging period of engine motoring at 75 to 100 percent firing speed (1500 - 2000 r.p.m.)

3.4.17 Thrust Indication. - No provisions for thrust indication shall be provided.

3.7 Drawing and Data. - The following Continental Aviation and Engineering Corporation drawings form a part of this specification:

Engine Installation	-	Drawing No. 705500
Engine Assembly	-	Drawing No. 705501

3.8.3 Change in Vendors. - The requirements of this paragraph are revised to read: - Changes made in vendors or fabrication sources shall be in accordance with the provisions of ANA Bulletin No. 423a; Specific substantiation test procedures for each item shall not be required. Substantiation procedures shall be as agreed between the contractor and the using service.

3.11 Electrical System. -

3.11.1.1 External Electrical Power. - The estimated power requirements of the engine which must be supplied from sources external to the engine shall be as follows:

	Volts	Maximum Amperes at 60^{o}F.	Approximate Rotor R. P. M.
Starting Fuel Solenoid	10-30 DC	2.0	2000-6000
Ignition Coil	10-30 DC	3.0	2000-6000

3.12 Dry Weight of Complete Engine. - The dry weight of the complete engine shall not exceed 365 pounds including the following components; fuel pump, fuel control system, oil pumps, oil filter, ignition system, thermocouples and harness, air starting manifold, and integral oil reservoir.

3.12.1 Weights of Additional Equipment. - The following additional equipment may be furnished by Continental Aviation and Engineering Corporation:

Oil Cooler 5 lb.

3.12.2 Weights of Residual Fluids. - The weight of the fluids remaining in the engine following operation and drainage is estimated to be 3.2 lb.

3.14 Flight Maneuver Forces. - In addition to the requirements of this paragraph, the engine and its supports shall operate satisfactorily when subjected to the load factors and angular velocities as summarized in Table 3. In addition, transient "R" loadings up to to 259g shall be permissible providing they are limited to a total of 30 minutes per 1000 hours of operation and to a duration not to exceed one (1) minute per occurrence.

The direction of engine loads summarized in Table 3 are as shown in Figure 27.

3.14.1 Simulated Flight Maneuver Forces. - The engine and its supports shall not experience structural failure when subjected to overloads equivalent to 1.5 times the values specified in paragraph 3.14 and Table 3. Such overloads may, however, render the engine inoperable.

TABLE 3 - FLIGHT/MANEUVERING LOADS AND VELOCITIES

g Field Summary					Condition	Angular Velocity Summary	
Load	Cont.	Altern.	Freq.	% of Time		Pitching Velocity - Ø	In-Plane Velocity -
- R	235	± 10	1	5	Hovering Flight		Hovering (7% of Time) Normal Operation-10.8 rad /sec. Overspeed-11.3 rad / sec. for 1 minute per occurrence for a total of 30 minutes per 1000 hours of total flight time.
		± 20	0.2	2			
		± 1	6	1			
F	-	± 5	1	5			
		± 2	0.2	2			
		± 3	6	1			
V	1	± 40	1	5			
		± 20	1	2			
		± 10	0.67	1			
R	195	± 10	1	5	Cruise - Flight	Cruise (50% of Cruise Flight Time) ± 1 rad/sec. at a frequency of 1 per helicopter rotor rev.	Cruise (93% of Time) Normal Operation-9.8 rad /sec. Harmonic variation of ± 0.25 rad /sec. at a frequency of 1 per helicopter rotor rev. for 50% of the cruise flight time.
		± 20	0.2	2			
		± 1	6	1			
		± 5	1	50			
H	-	± 5	1	5			
		± 2	0.2	2			
		± 3	6	1			
		± 3	3	50			
V	1	± 40	1	5			
		± 20	1	2			
		± 10	0.67	1			
		± 15	2	49			
		± 25	2	1			
					Maneuvering Flight	± 3 rad /sec. at a frequency of 1 per helicopter rotor rev. for 2% of the total flight time.	

3.16.1 Mass Moment of Inertia of Rotating Parts. - The effective mass moment of inertia of the rotating parts, about the rotor axis, is 9.3 pound-feet squared.

3.17 Engine Vibration. - The maximum permissible case displacement, at or above 110 c.p.s., when measured laterally (side-to-side) or vertically in the vibration measuring plane specified on the installation drawing shall not exceed the following:

	Engine R.P.M.	Maximum Double Amplitude (Peak-to-Peak) Displacement - Mils.
Front Pickup	Over 16,000	1.5
	Below 16,000	3.5
	Below 16,000	5.0 transient
Rear Pickup	Over 16,000	1.5
	Below 16,000	3.5
	Below 16,000	5.0 transient

3.18 Compressor Air Bleed. - Provisions for extraction of compressor bleed airflow, other than that specified in paragraph 3.21 (Anti-Icing) of this specification, shall not be made.

3.19.1 Engine Heat Rejection. - The estimated sea level heat rejection is shown in Figure 21.

3.19.2 Limiting Zone Temperature. - All external zones of the engine shall be capable of continuous operation when surrounded by air at an ambient temperature of 250°F.

3.19.3 Oil Flow and Heat Rejection. - An air-to-oil heat exchanger may be furnished as engine mounted additional equipment. The estimated airflow requirement, the oil cooler air pressure drop, and the oil temperature differential shall be as listed below:

Required Airflow	Oil Cooler Air Pressure Drop	Oil Temperature Differential
2.0 lb/sec.	7 ± 1 inches H_2O	100°F.

3.20.1 Intake Protection. - An intake screen shall not be provided on the engine.

3.20.2 Inlet Duct Attachments. - The engine inlet duct attachments are of the bolted-flange type.

3.20.3 Inlet Air Pressure Variation. - The estimated radial and circumferential pressure distribution limits than can be tolerated without measurable performance loss shall be ± 3 percent of the mean inlet total air pressure, measured at the engine inlet. The estimated maximum variation which can be safely tolerated shall be ± 7-1/2 percent of the mean inlet total air pressure. Performance losses with variation greater than ± 3 percent will be presented in a subsequent revision of this specification.

3.20.4 Inlet Connection Loads. - The maximum allowable loads which may be applied at the inlet flange shall be as follows:

Shear	-	300 pounds
Axial	-	300 pounds
Overhung Moment	-	800 inch-pounds

3.21.1 Type of Anti-Icing. - Anti-icing operation shall be noncontinuous and activated by pilot command by means to be airframe furnished. The specific operational system requirements shall be specified in a subsequent revision of this specification.

3.21.2 Accessory Section Connection. - A connection on the combustor housing shall be available for airframe nacelle anti-icing. The quantity of bleed air extracted shall not exceed 3 percent of the total airflow from idle position to military position.

3.24.1 Exhaust Connections. - The requirements of this paragraph are not applicable.

3.24.2 Exhaust Nozzle. - The exhaust nozzle shall be an integral part of the engine and is of the fixed area type.

3.24.3 Duct Attachment. - No exhaust connections shall be required.

3.25 Lubricating System. - An integral oil reservoir of 24 quarts total volume is furnished with the engine. Oil level is determined with a sight glass oil level indicator. Filling shall be accomplished manually and an "O" ring seal filler cap is provided.

3.25.1 Oil Supply. - The capacity of the oil reservoir is as follows:

Usable Oil	-	1.5 gal.
Unusable Oil	-	0.3 gal.
Expansion Space	-	4.5 gal.

3.25.5 Oil Pressure and Temperature. - The operating oil pressure shall be 40 $\pm$ 5 p.s.i.g. within the normal static gravity field and 175 $\pm$ 10 p.s.i.g. when operating within the 235g field. The maximum allowable engine oil inlet temperature shall be 250°F. (122°C.). The maximum allowable oil system temperature shall be 350°F. (177°C.).

The normal oil pressure and temperature ranges required for aircraft cockpit indicators shall be 0 to 200 p.s.i.g. and -65°F. (-54°C.) to 300°F. (150°C.), respectively.

3.26 Fuel System. - The following requirements shall be subject to revision following rotation testing.

3.26.1.1 Performance With Assistance From Aircraft Boost Pump. - This paragraph shall apply except the fuel pressure range of subparagraph b shall be: From 10 p.s.i. above the true vapor pressure of the fuel to 3000 p.s.i.g.

3.26.1.2 Performance Without Assistance From Aircraft Boost Pump. - The engine shall start and operate as specified within this specification when supplied with fuel, at the engine inlet, as specified in paragraph 3.26.1.2 of Specification MIL-E-5007B except that the vapor/liquid ratio specified in subparagraph d shall be revised to read: zero to 0.3.

3.26.5 Fuel Filters. - The requirements of this paragraph shall apply except that the referenced fuel contamination shall be as specified in paragraph 3.4.1.3 of this specification.

3.26.6 Fuel Flowmeter. - Provisions shall not be made for flowmeter installation.

3.27 Engine Control System. - The fuel control system is basically a W_f/P_{cd} scheduling system, established by a 3-D cam as a function of engine speed and inlet air temperature. The system performs the function of pumping and scheduling fuel to the engine to properly permit starting, acceleration, speed governing, deceleration and fuel shut off.

In the pumping and metering section of the control, the functions of boost pressure regulation, fuel pumping, ignition fuel flow supply, main fuel metering, servo pressure generation, and fuel shut off are performed.

A computer section receives the engine-sensed input and provides intelligence for metering valve positioning which, due to a relatively constant valve pressure drop, provides fuel flow control proportional to the metering valve area.

3.27.2 Starting Procedure. - The normal starting procedure shall be as listed below:

a. Rotate engine to starting speed of 2000 r.p.m. (air impingement, windmilling, or other).

b. Move throttle to Ignite Position.

c. Energize Ignition Switch to ON (permits fuel flow to engine starting fuel nozzles and activates ignition exciter coil).

d. When visual evidence of ignition is received, move throttle to Idle Position.

e. Turn Ignition Switch to OFF at approximately 6000 r.p.m.

3.27.3 Power Lever. - The relation of the power lever to engine speed is as shown in Figure 22. Provision is not made for reverse thrust operation.

3.27.4 Control System Adjustments. - In service control adjustments shall be limited to idle position limits, maximum position limits, and fuel density. These adjustments shall be readily accessible, adjustable with the engine in operation, and clearly marked.

3.28 Ignition System. - The components furnished and their normal operation when supplied with nominal input requirements shall be as listed below:

No.	Component	Nominal Input	Normal Operation
2	Igniter Plugs and Leads	Igniter Coil Output	A minimum 4 sparks per second, at a 10 volt DC input, at an electrical stored energy level of 0.625 joules/spark, per plug.
1	Ignition Coil	10-30 Volts DC	Satisfactory operation of igniter plugs.

3.29 Accessory Drives. - An engine speed output signal shall be provided integral with the fuel control. The required sensing unit shall be of the frequency counting type. The output signal shall be as shown in Figure 23.

4. QUALITY ASSURANCE PROVISIONS

4.3 Qualification Tests. - Qualification of the engine shall be predicated upon the satisfactory completion of qualification tests substantially equivalent to the requirements as specified in Specification MIL-E-5009B. Specific tests to demonstrate the capability of the engine to operate in extreme force fields shall be mutually agreed upon with the Using Service, following Whirl Rig tests. Satisfactory completion of tests shall include Using Service approval of the test reports. The qualification tests shall be specified in a subsequent revision of this specification.

4.4 Preliminary Flight Rating Tests. - This paragraph not applicable to this preliminary qualification engine specification.

4.5 Acceptance Tests. - An acceptance test shall be conducted on each production engine. Acceptance shall be predicated upon the satisfactory completion of engine tests substantially in accordance with Specification MIL-E-5010B and modified, as mutually agreed upon with the Using Service, to demonstrate extreme force field operation capability. The acceptance tests shall be specified in a subsequent revision of this specification.

5. PREPARATION FOR DELIVERY

5.1 Preparation for Storage and Shipment. - The engine, components, and accessories shall be prepared for storage and shipment in accordance with Specification MIL-E-5607A or with previously approved manufacturer's procedures.

6. NOTES

6.2 Definitions and Symbols. - The symbols used in this specification are defined as follows:

Symbol	Quantity	Unit
F	Thrust	lb.
F_g	Gross thrust	lb.
F_n	Net jet thrust ($Fn = F_g - F_r$)	lb.
F_r	Ram drag of engine airflow taken on the basis of total induction airflow	lb.
g	Acceleration due to gravity	ft /sec.^{2}
ϕ	Rotation about the engine axis	rad /sec.
Ω	Rotation about the helicopter axis	rad /sec.
N	Engine speed	r.p.m.
P	Absolute pressure	p.s.i.
P_s	Standard sea level pressure, absolute	p.s.i.
P_{am}	Ambient static pressure, absolute	p.s.i.
P_t	Any gas total pressure, absolute	p.s.i.
T	Absolute temperature	°Rankine
T_s	Standard sea level temperature	°Rankine
T_{am}	Ambient static temperature	°F
T_t	Any gas total temperature	°Rankine
V	Velocity relative to undistrubed ambient air	knots

Symbol	Quantity	Unit
s. f. c.	Specific fuel consumption	lb /hr /lb. -thrust
W_a	Total engine airflow	lb /sec.
W_f	Engine fuel flow	lb /hr.
HP_{ext}	Horsepower extracted from the accessory drives over and above that required for engine components	horsepower
HP_{ref}	Reference horsepower; arbitrarily taken as 10 percent of the horsepower in the jet at static sea level conditions	horsepower
δ	Relative pressure, P/P_s. Air, δ, and P have subscripts referring to any particular station	nondimensional
θ	Relative temperature, T/T_s, air, θ, and T have subscripts referring to any particular station	nondimensional
C_d	Duct loss correction to thrust	nondimensional

Inlet duct loss

$$\Delta F/F_n = \Delta P_{t2}/P_{t2} \ (C_d - 1)$$

Exhaust duct loss

$$\Delta F/F_n = C_d \ (\Delta P_{t5}/P_{t5})$$

C'_d	Duct loss correction to fuel flow	nondimensional

Inlet duct loss

$$\Delta W_f/W_f = \Delta P_{t2}/P_{t2} \ (C'_d - 1)$$

Exhaust duct loss

$$\Delta W_f/W_f = C'_d \ (\Delta P_{t5}/P_{t5})$$

C_{px}	Power extraction correction to thrust	nondimensional

$$\Delta F/F_n = C_{px} \ (HP_{ext}/HP_{ref})$$

Symbol	Quantity	Unit
C'_{px}	Power extraction correction to fuel flow	nondimensional

$$\Delta W_f/W_f = C'_{px}\,(HP_{ext}/HP_{ref})$$

6.2.1 Subscripts. - The subscripts employed in this specification are in accordance with the following:

Subscript	Meaning
a	air
am	ambient-static values of undistrubed air mass
f	fuel
j	jet
n	net
s	standard sea level values
t	total
2, 3, 5	station subscripts (refer to Figure 26)

6.3 Method for Correcting Estimated Performance. - The following sample computation relates to Inlet and Exhaust Duct Losses, and Power Extraction:

a. Find the net thrust and fuel flow for:

3 percent inlet duct pressure loss,
2 percent exhaust duct pressure loss,
5 horsepower power extraction.

For the following flight conditions:

N = 100 percent
h = 25,000 ft.
V = 600 knots T.A.S.

The following equation shall be used in determining net thrust:

$$\frac{\Delta F_n}{F_n} = (C_d - 1)\left(\frac{\Delta P_{t2}}{P_{t2}}\right) + C_d\left(\frac{\Delta P_{t5}}{P_{t5}}\right) + C_{px}\left(\frac{HP_{ext}}{HP_{ref}}\right)$$

From Figure 4 we obtain the following ideal net thrust, 962 pounds, and the fuel flow, 1172 pounds per hour, for the specified flight conditions.

Substitute the following values for the parameters in the equation.

From Figure 5, $C_d = -.60$ $C'_d = 0$ for all flight conditions

From Figure 7, $C_{px} = .072$ $C'_{px} = 0$ for all flight conditions

$$\Delta F_n = 962\ (-1.62 \times .03 - .60 \times .02 + .072\ \frac{5}{300})$$

$\Delta F_n = -57.1$; thus $F_n = 904.9$

The following equation shall be used in determining fuel flow:

$$\Delta W_f/W_f = (C'_d - 1)\ \Delta P_{t2}/P_{t2} + C'_d\ \Delta P_{t5}/P_{t5} + C'_{px}\ HP_{ext}/HP_{ref}$$

Substitute the aforementioned values of C'_d, C'_{px} in the equation:

$\Delta W_f = -35.6$; thus $W_f = 1136.4$ lb/hr.

The following sample computation illustrates the effect of Ambient Temperature.

b. Find the Net Thrust, Fuel Flow, and Airflow for the following flight conditions at Military Power Rating:

N = 100 percent
h = 15,000 ft.
T_{am} = 60°F
V = 400 knots T.A.S.

From Figure 3, at standard altitude conditions:

F_n = 1081
s.f.c. = 1.19 lb/hr/lb. - thrust
W_f = 1.19 x 1081 = 1287 lb/hr.
W_a = 21.5 lb/sec.

From Figure 12, $\dfrac{\Delta F_n}{F_n} = -.185$

From Figure 14, $\dfrac{\Delta W_f}{W_f} = -.12$

From Figure 16, $\dfrac{\Delta W_a}{W_a} = -.13$

Therefore,

ΔF_n = -.185 x 1081 = -200 lb., and F_n = 1081 - 200 = 881 lb.

ΔW_f = -.12 x 1287 = -154 lb/hr., and W_f = 1287 - 154 = 1133 lb/hr.

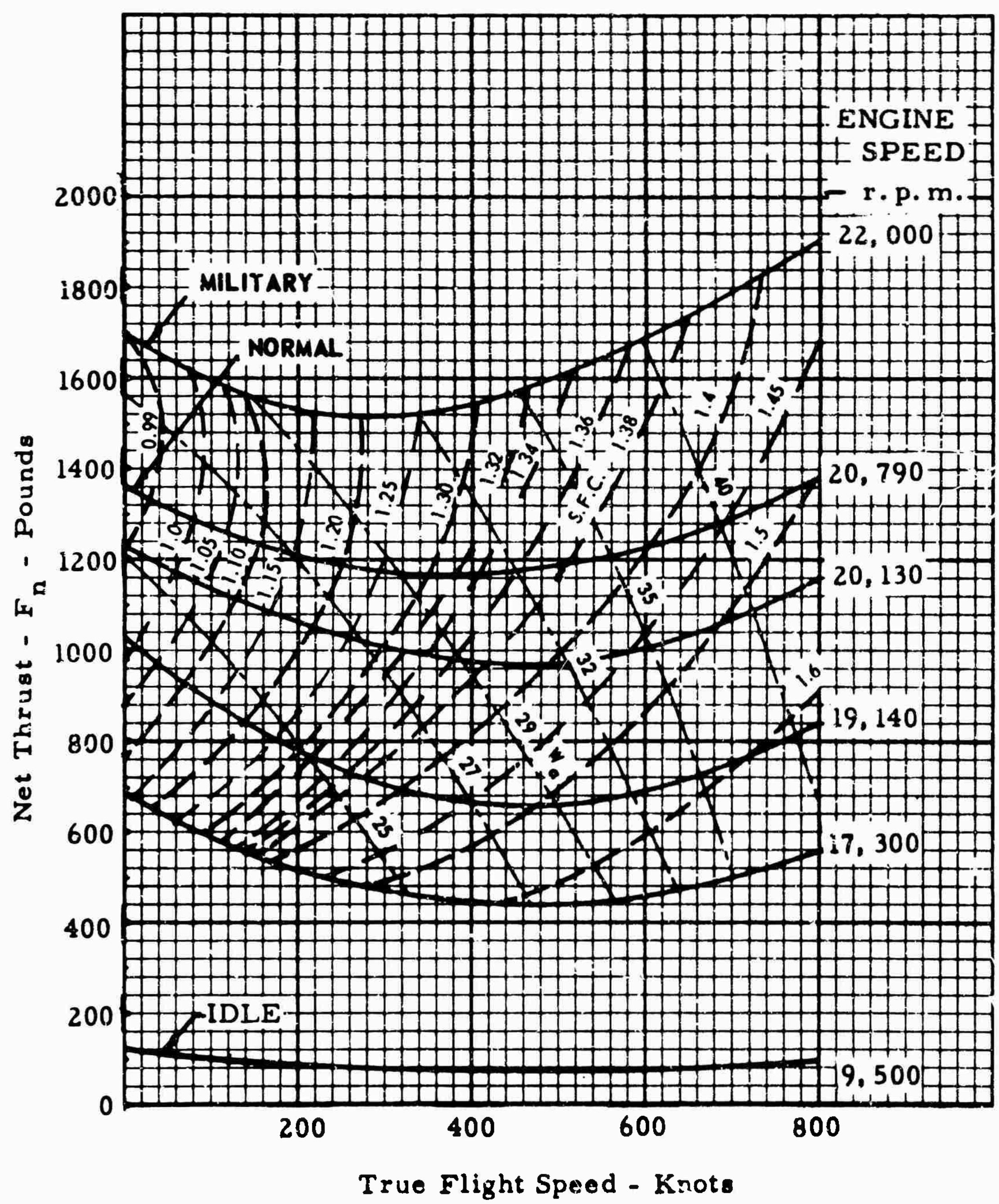
ΔW_a = -.13 x 21.5 = -2.8 lb/sec., and W_a = 21.5 - 2.8 = 18.7 lb/sec.

Specification No. 2253-A

FIGURE 1

CAE MODEL 357-1 TIP TURBOJET ENGINE
ESTIMATED PERFORMANCE CHARACTERISTICS

ALTITUDE - SEA LEVEL



Specification No. 2253

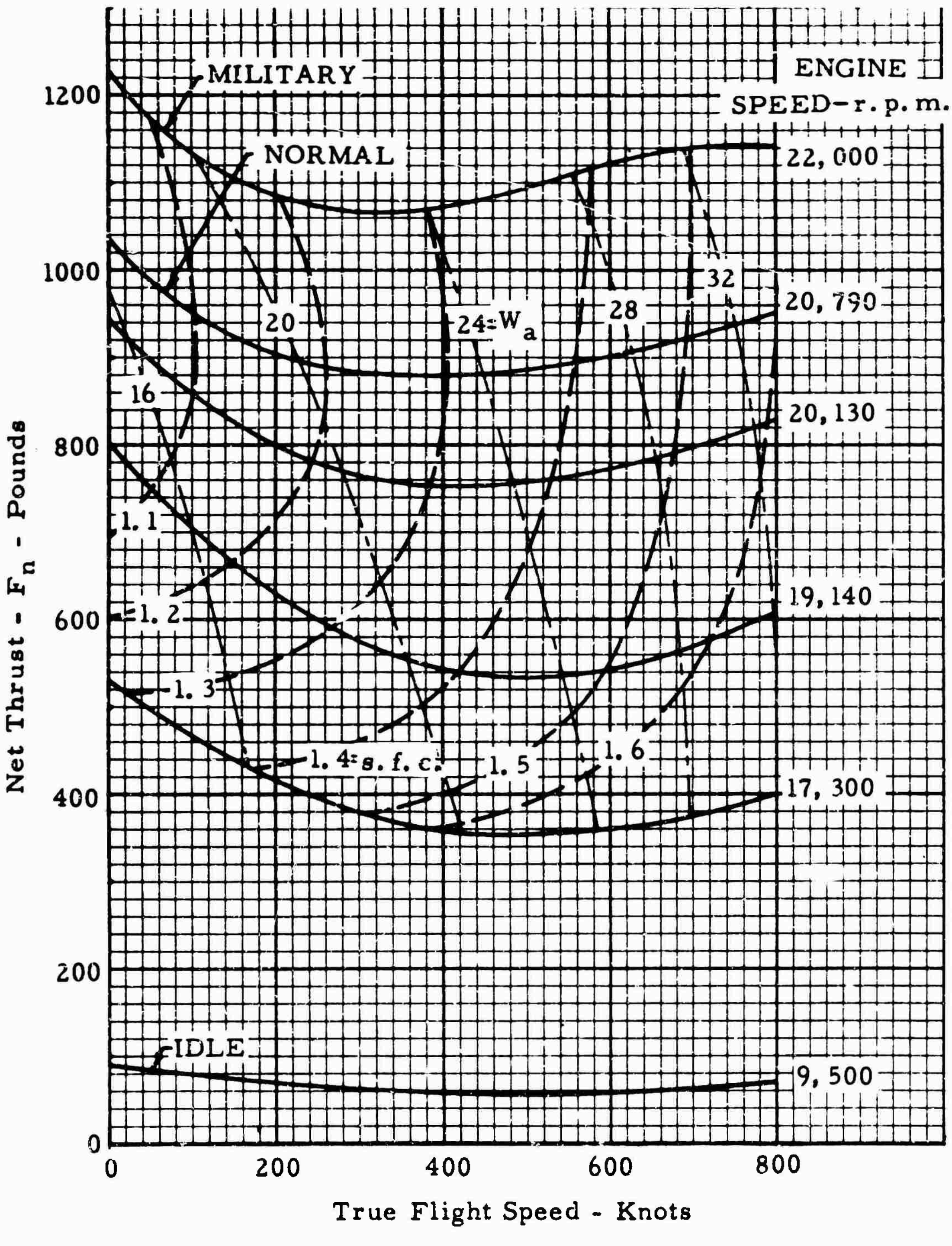
FIGURE 2

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED PERFORMANCE CHARACTERISTICS

95°F AMBIENT TEMPERATURE

ALTITUDE - 6,000 FEET



Specification No. 2253 -A

FIGURE 3

CAE MODEL 357-1 TIP TURBOJET ENGINE
ESTIMATED PERFORMANCE CHARACTERISTICS
ALTITUDE - 15,000 FEET

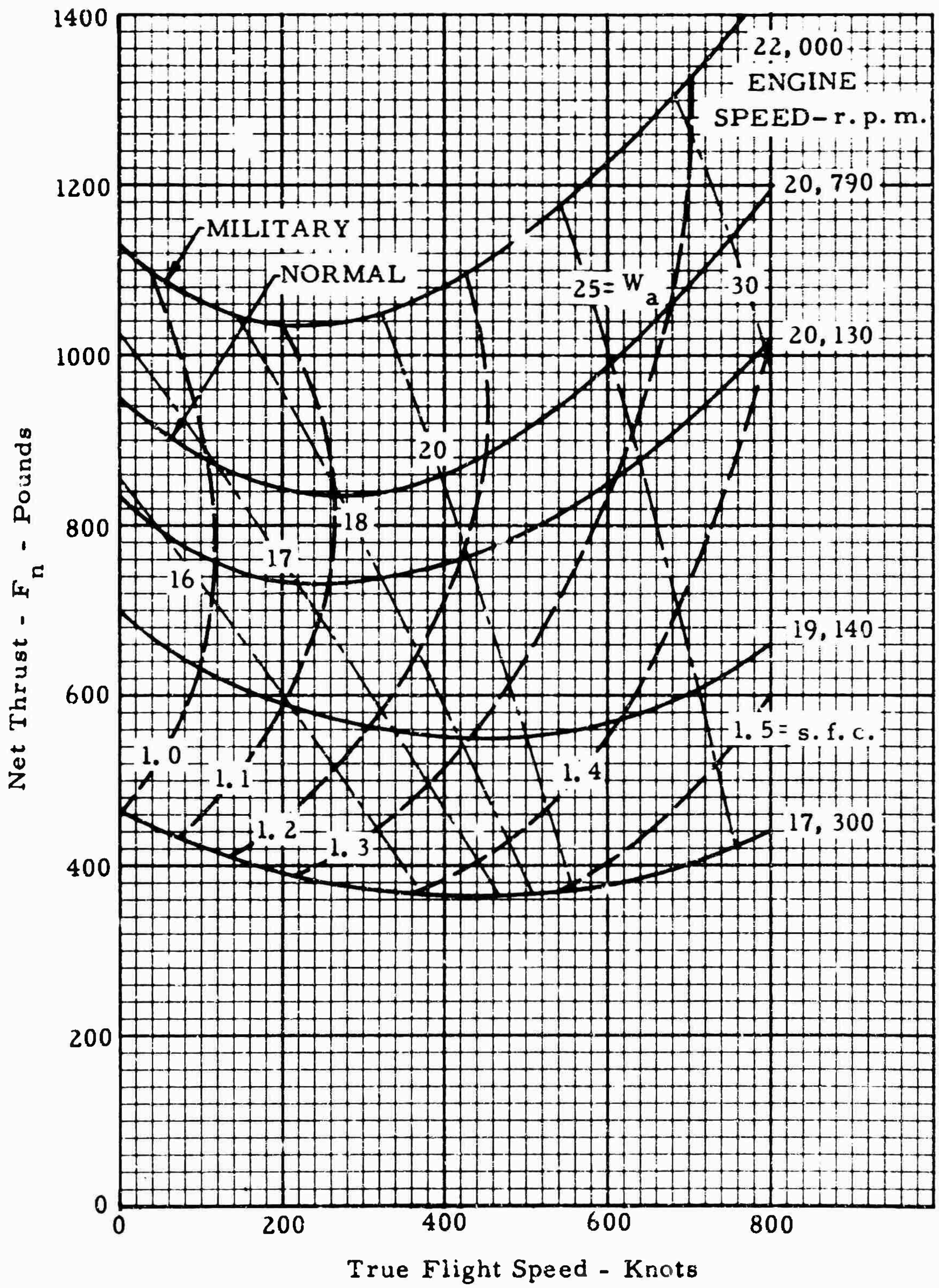


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FIGURE 4

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED PERFORMANCE CHARACTERISTICS

ALTITUDE - 25,000 FEET

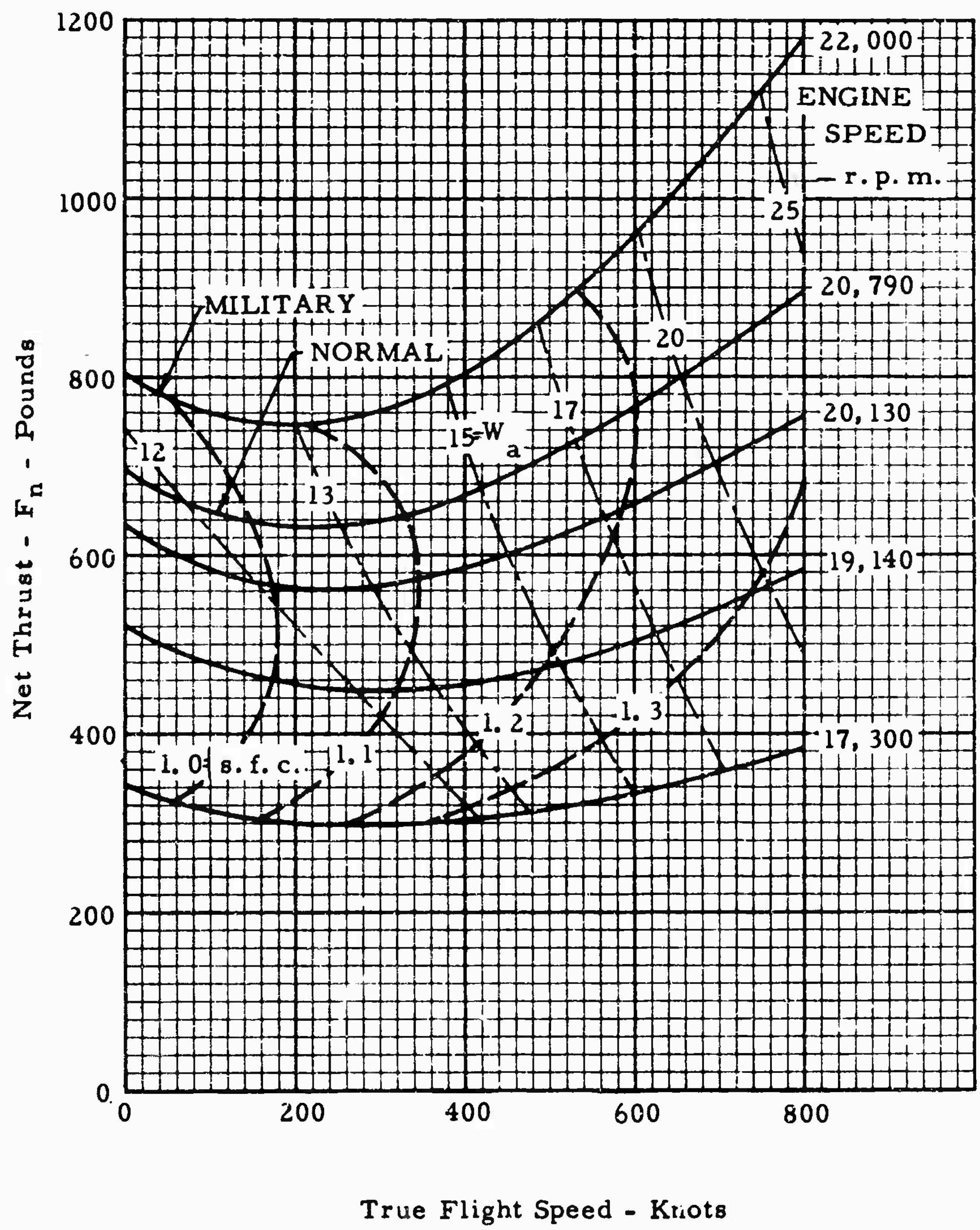

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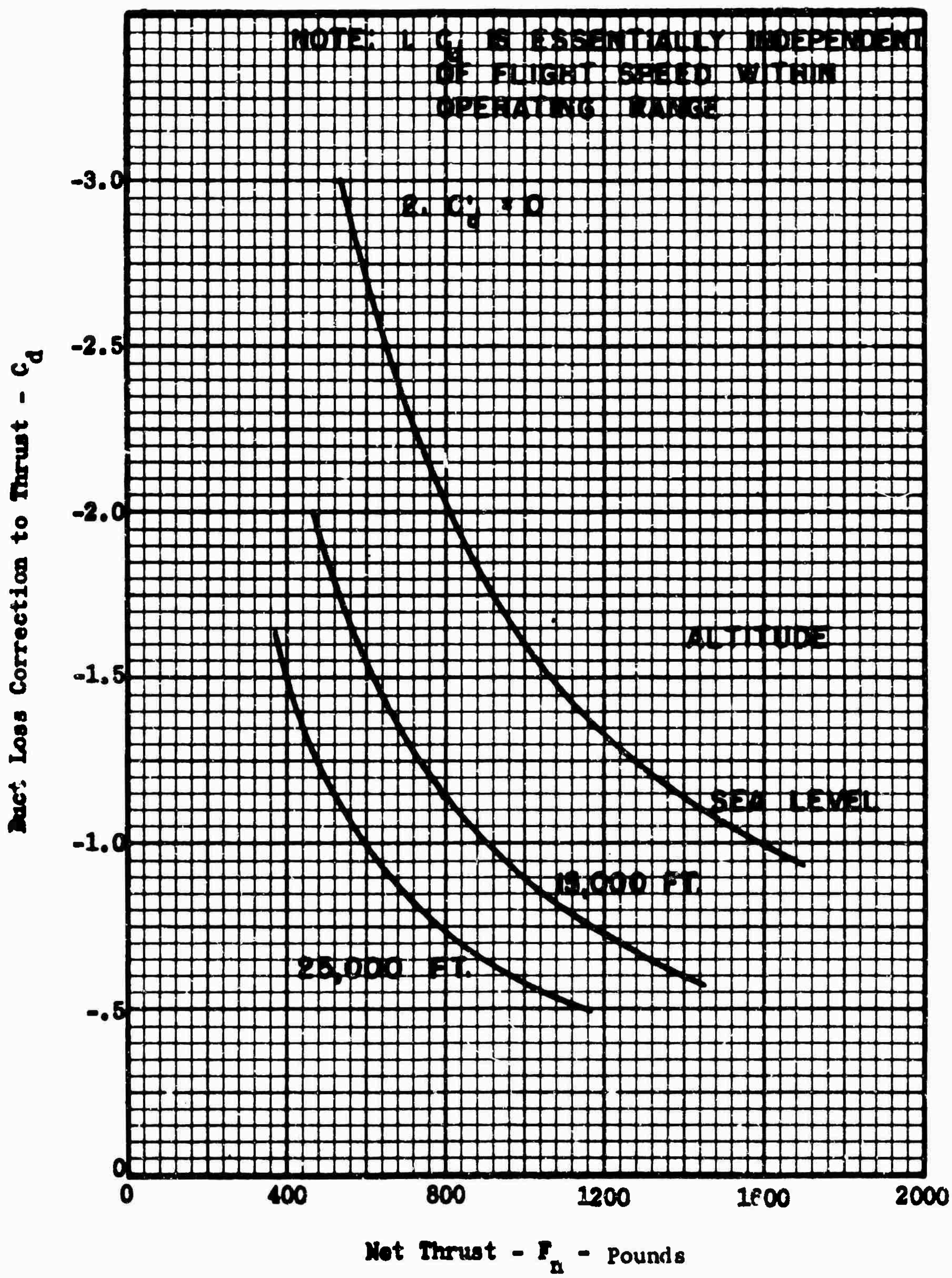
FIGURE 5

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED THRUST LOSS CORRECTION DUE TO DUCT LOSS



Specification No. 2253-A

FIGURE 6

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED POWER EXTRACTION CORRECTION
TO THRUST VERSUS THRUST
ALTITUDES - SEA LEVEL AND 15,000 FEET

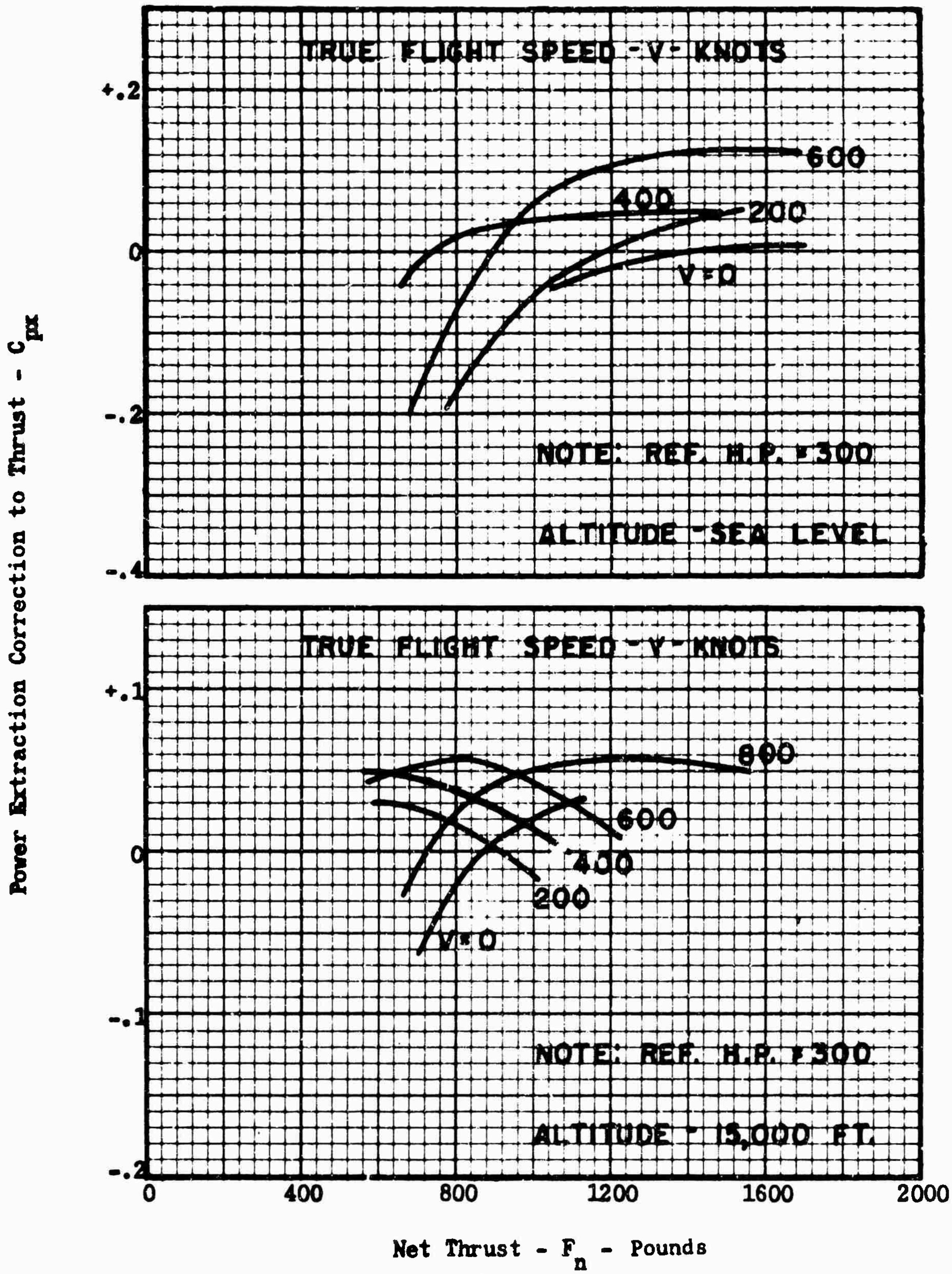
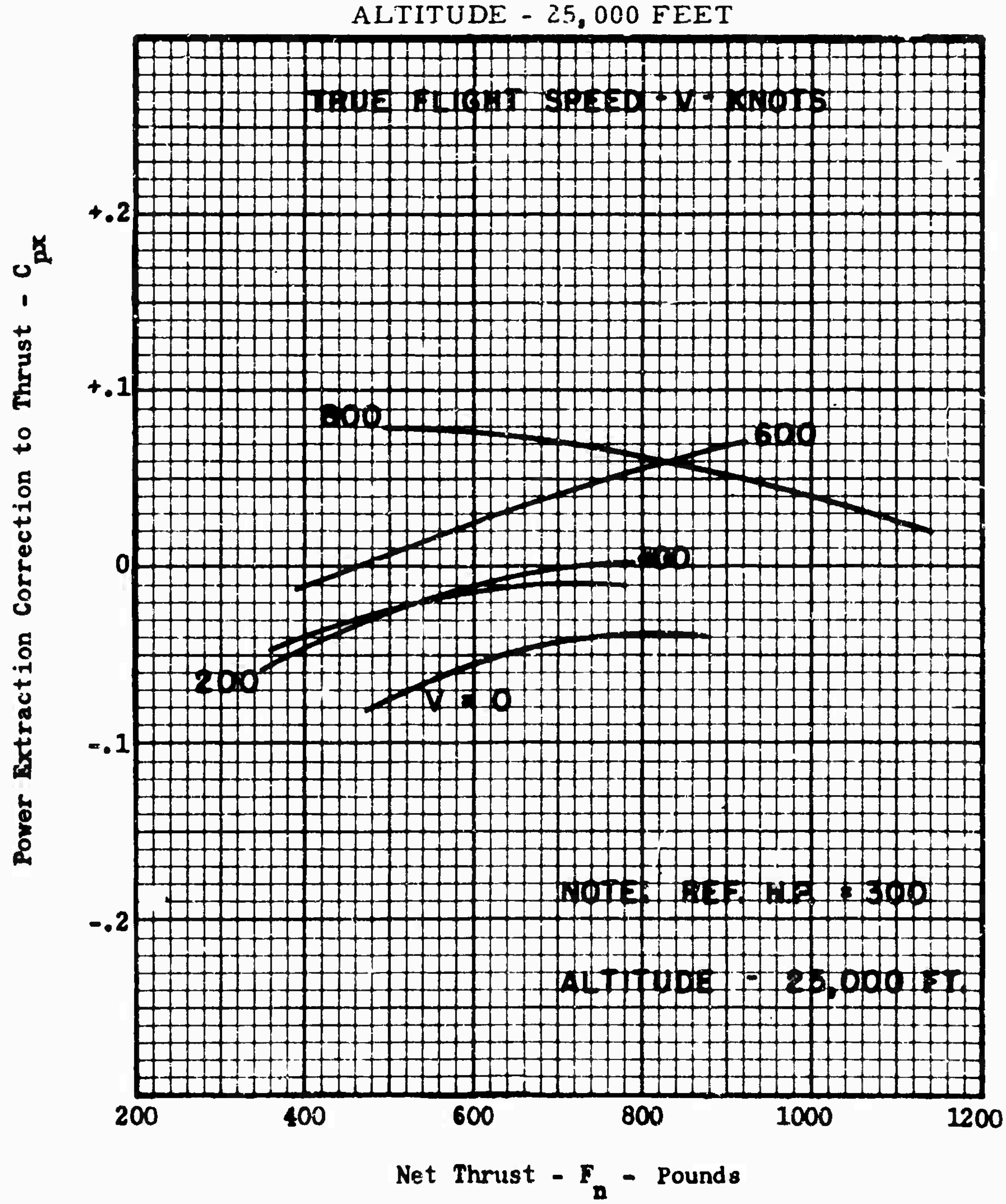


FIGURE 7

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED POWER EXTRACTION CORRECTION TO THRUST VERSUS THRUST

ALTITUDE - 25,000 FEET

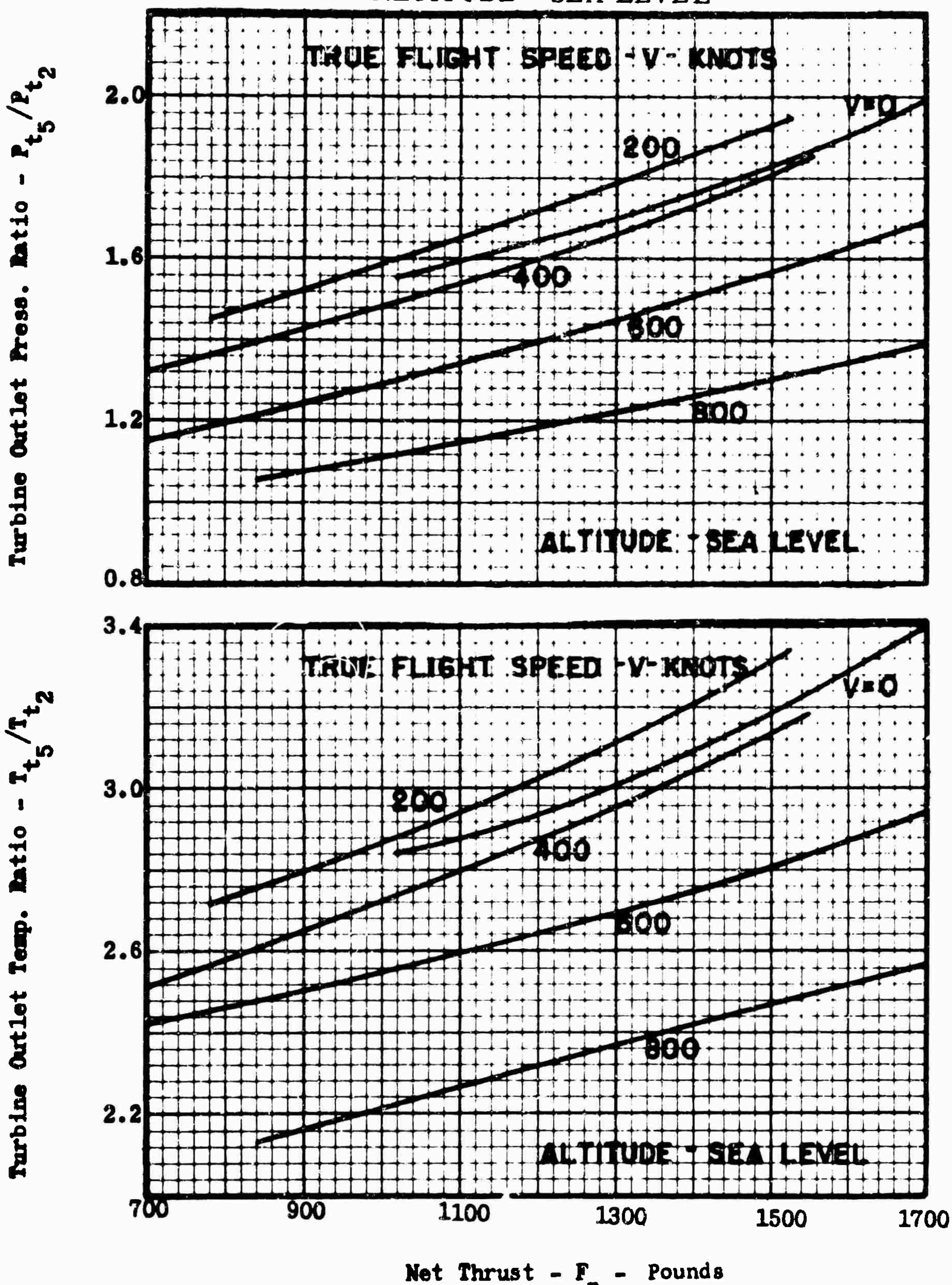


Specification No. 2253-A

FIGURE 8

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED TURBINE OUTLET PRESSURE
AND TEMPERATURE RATIOS
ALTITUDE - SEA LEVEL



Specification No. 2253-A

FIGURE 9

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED TURBINE OUTLET PRESSURE
AND TEMPERATURE RATIOS
ALTITUDE - 15,000 FEET

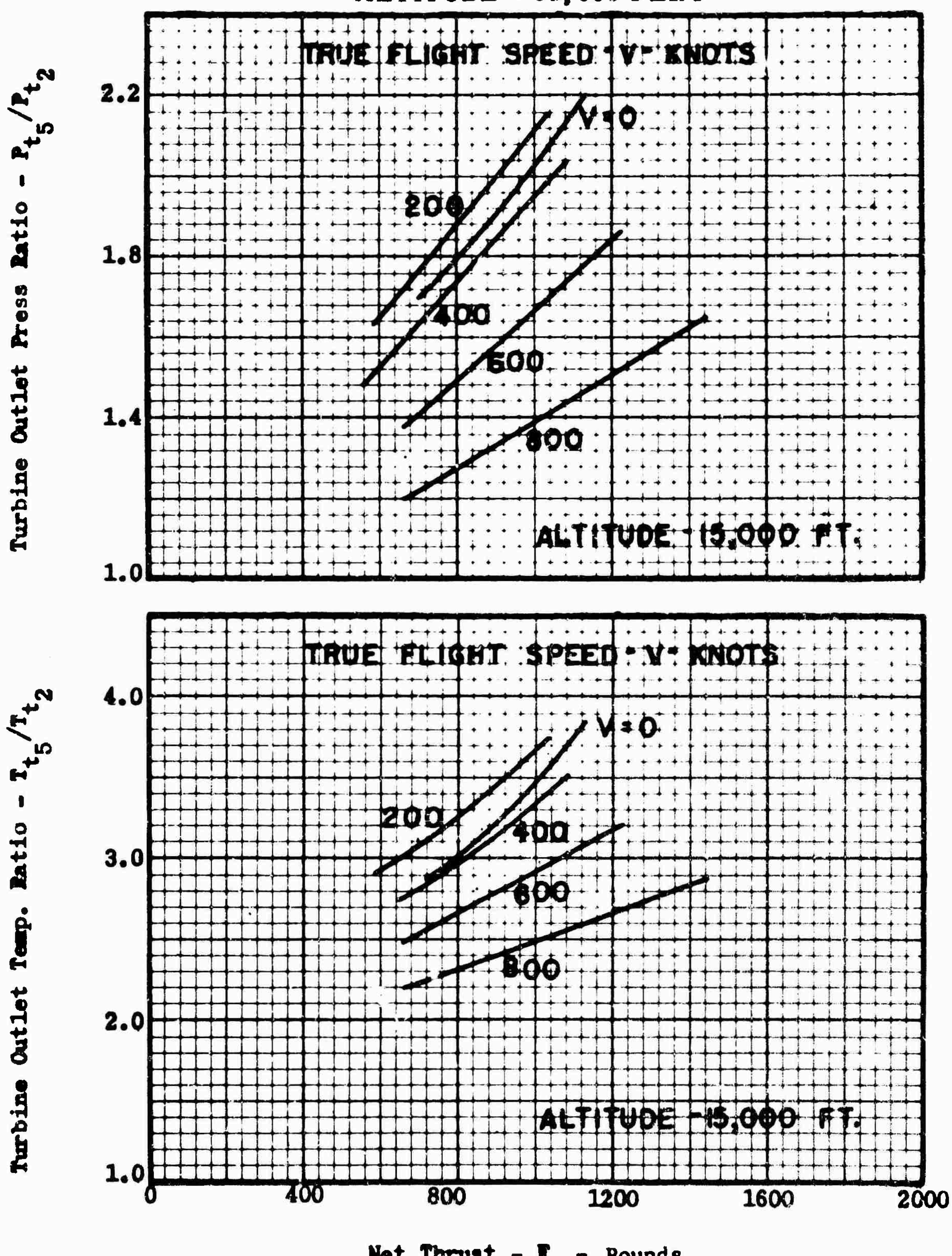


FIGURE ˙0

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED TURBINE OUTLET PRESSURE
AND TEMPERATURE RATIOS
ALTITUDE - 25,000 FEET

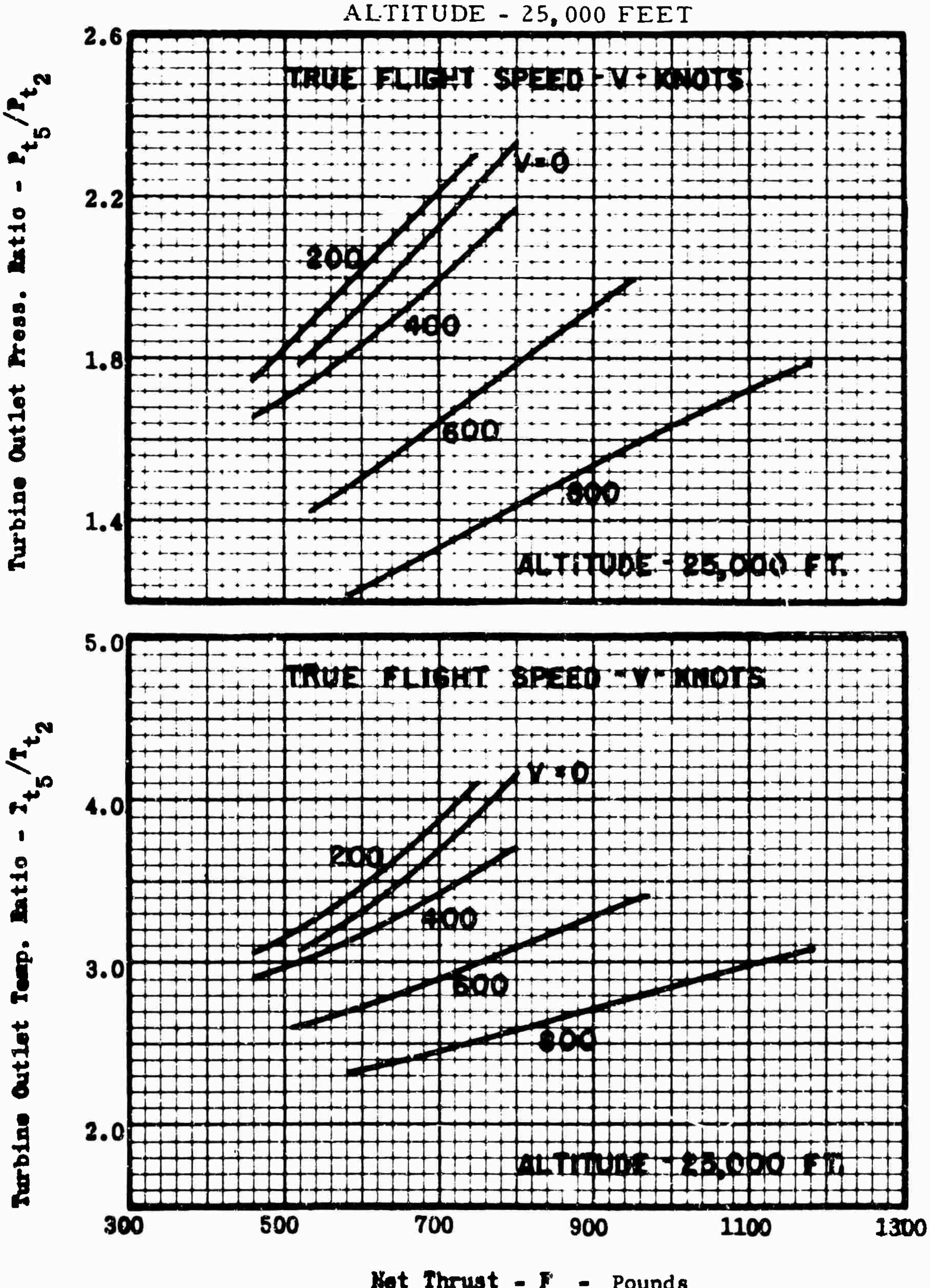


FIGURE 11

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED EFFECT OF AMBIENT TEMPERATURE ON THRUST

ALTITUDE - SEA LEVEL

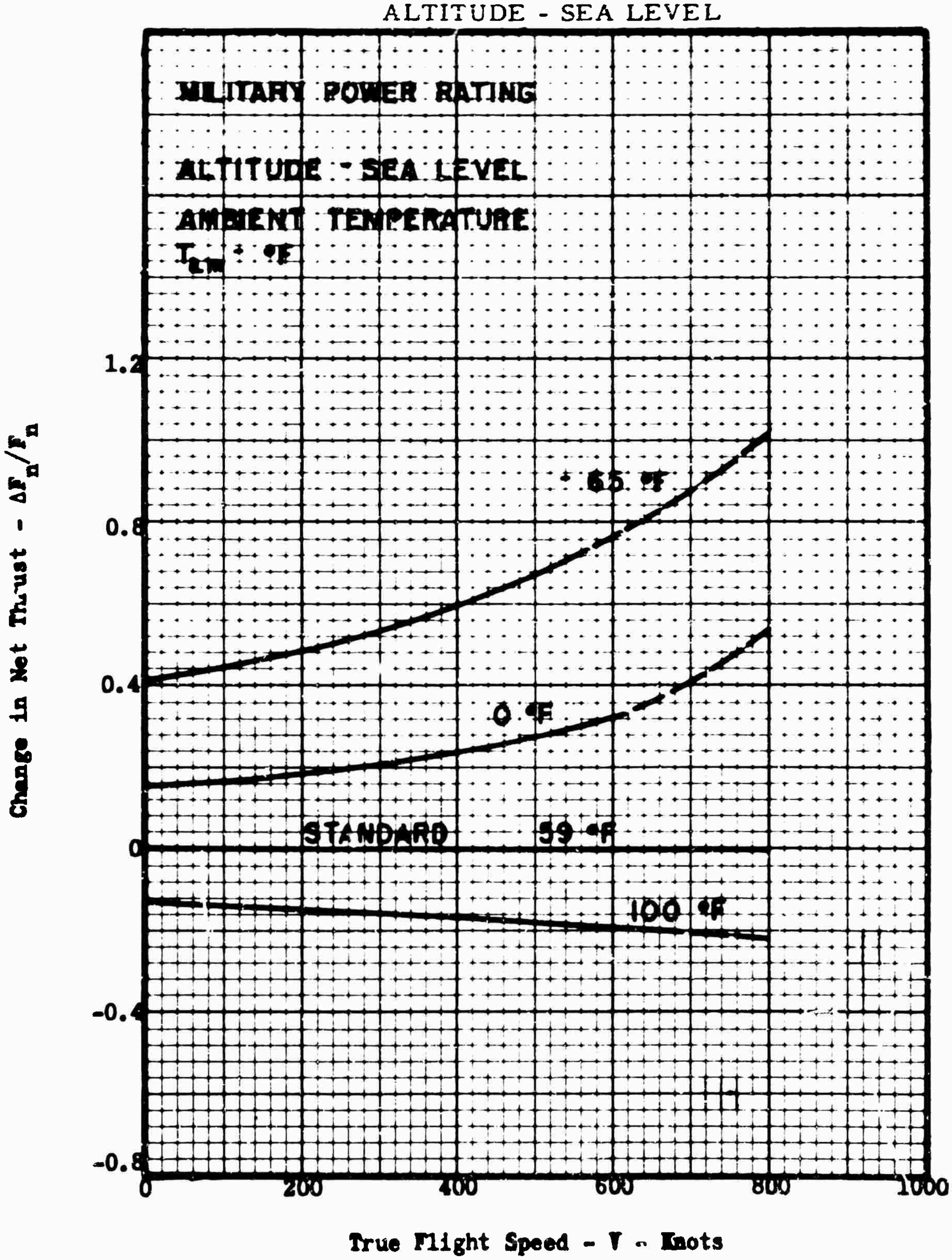
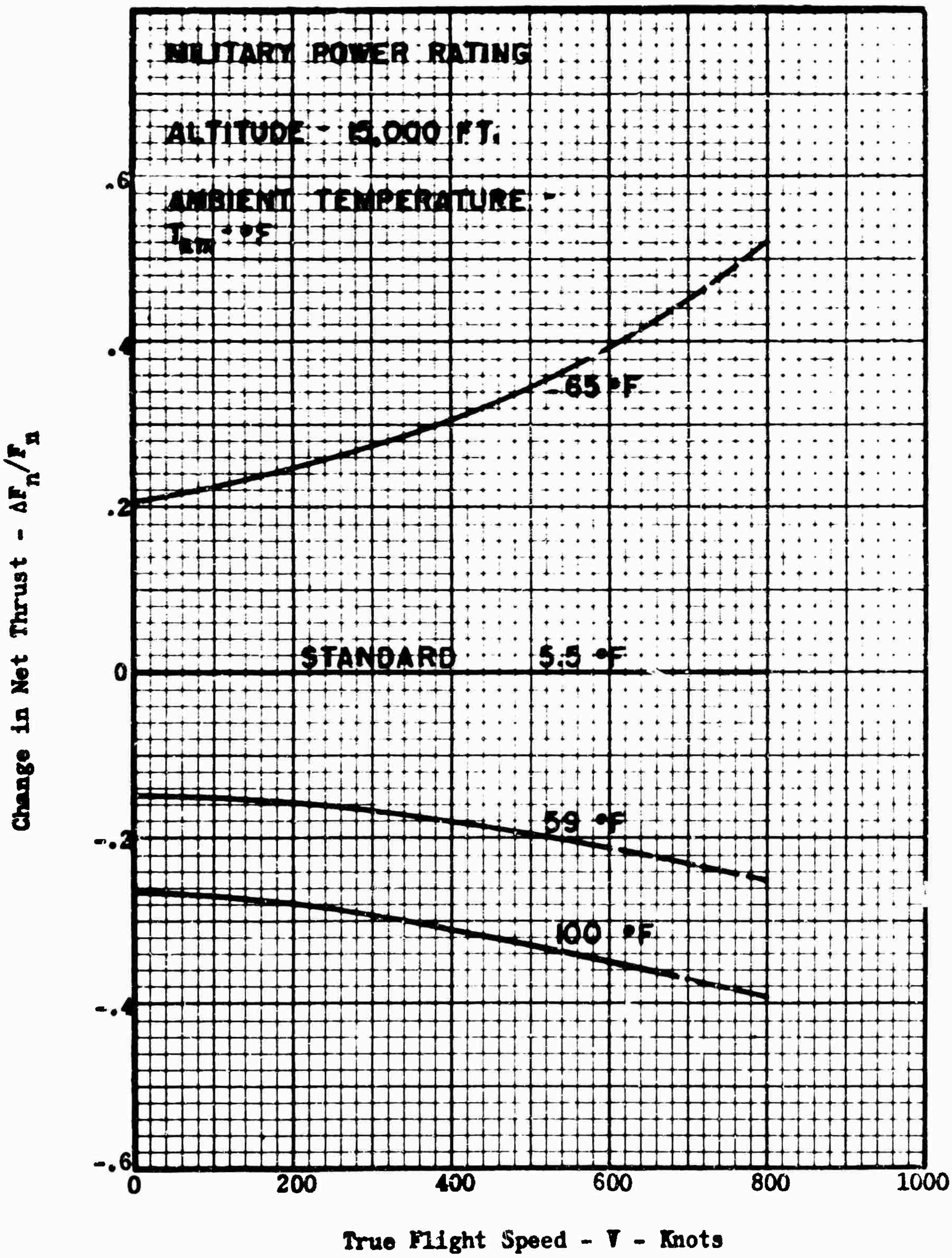


FIGURE 12

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED EFFECT OF AMBIENT TEMPERATURE ON THRUST

ALTITUDE - 15,000 FEET

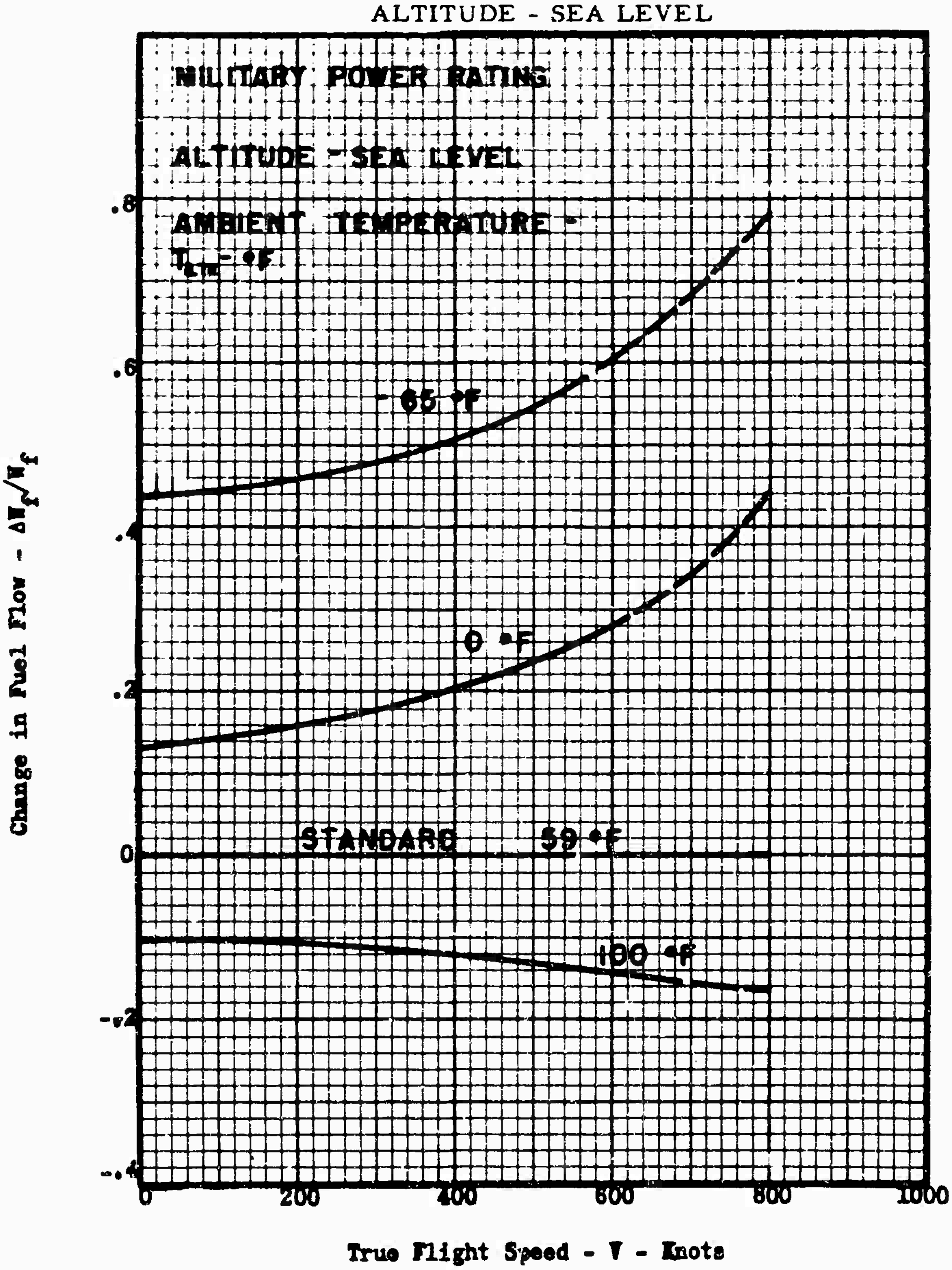


Specification No. 2253-A

FIGURE 13

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED EFFECT OF AMBIENT TEMPERATURE
ON FUEL FLOW
ALTITUDE - SEA LEVEL



Specification No. 2253-A

FIGURE 14

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED EFFECT OF AMBIENT TEMPERATURE ON FUEL FLOW

ALTITUDE - 15,000 FEET

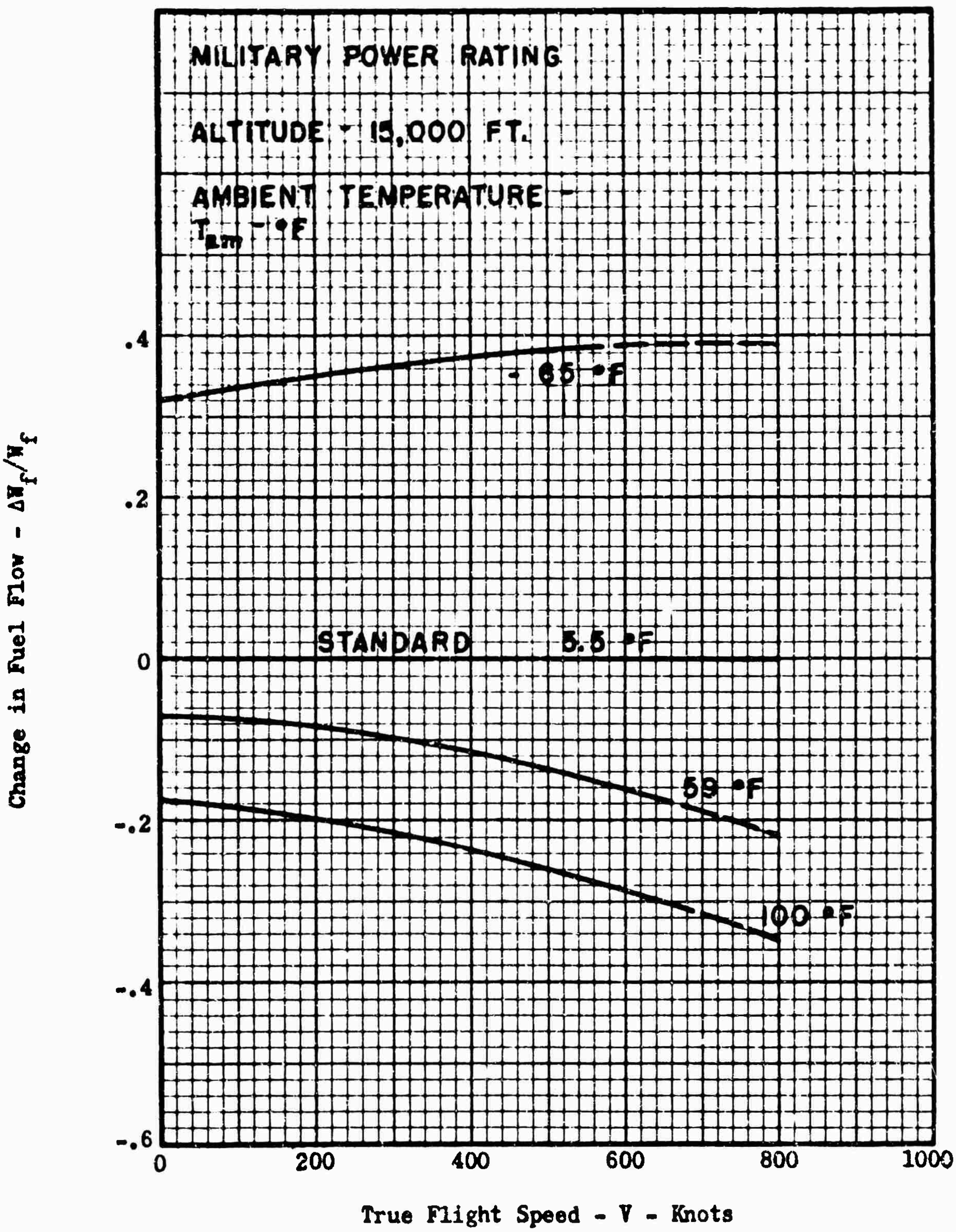


FIGURE 15

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED EFFECT OF AMBIENT TEMPERATURE ON AIRFLOW

ALTITUDE - SEA LEVEL

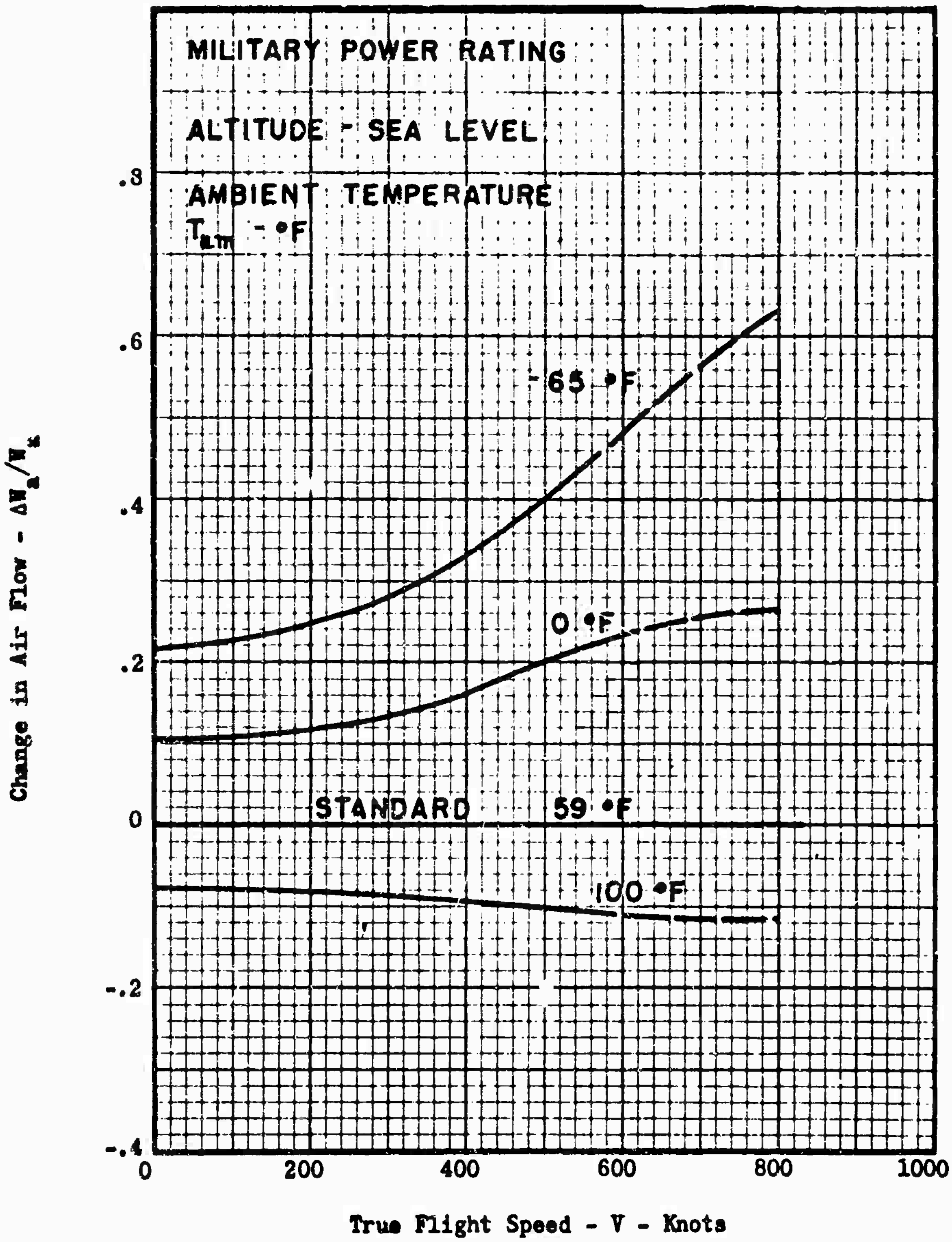


FIGURE 16

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED EFFECT OF AMBIENT TEMPERATURE ON AIRFLOW

ALTITUDE - 15,000 FEET

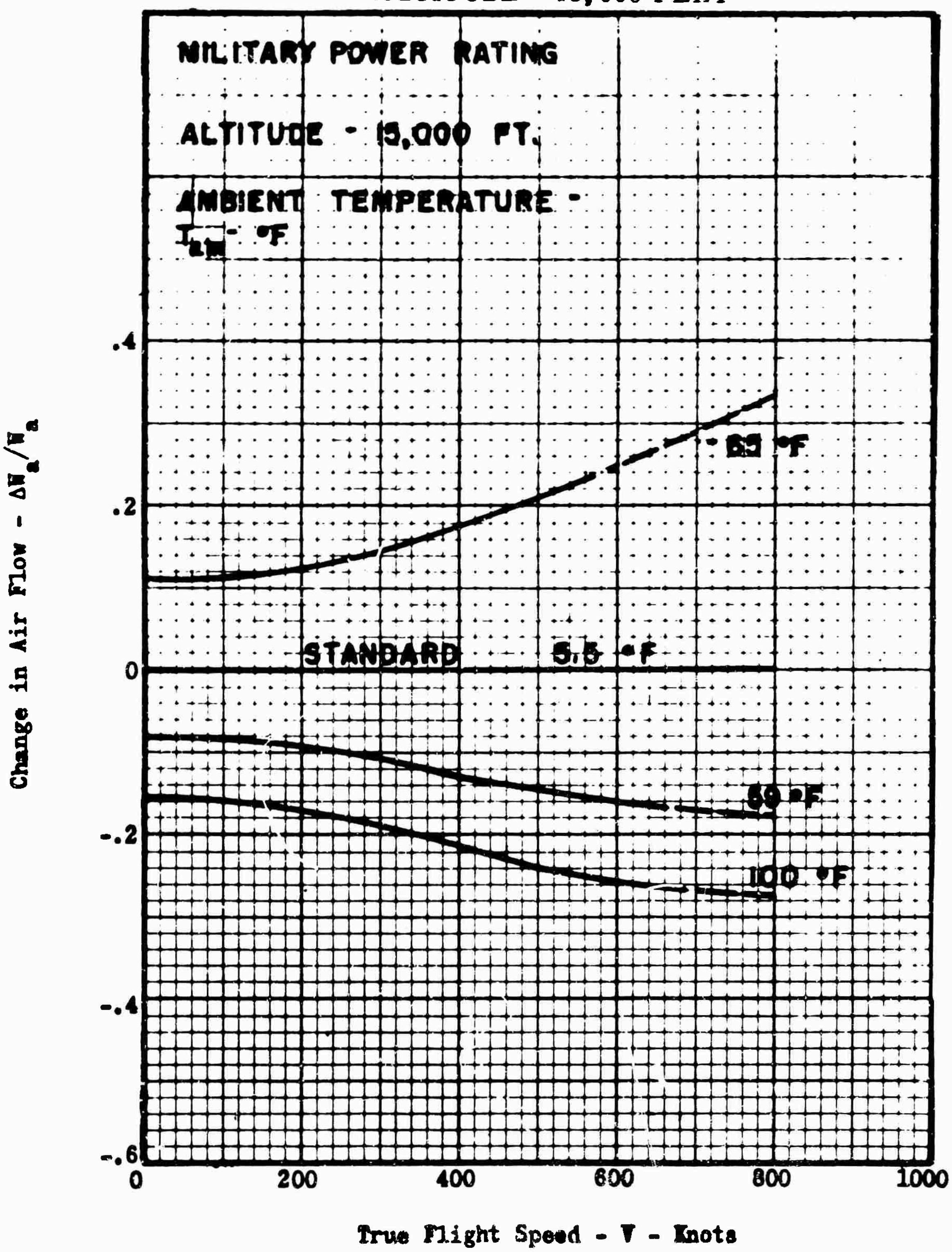


FIGURE 17

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED ENGINE OPERATING LIMITS

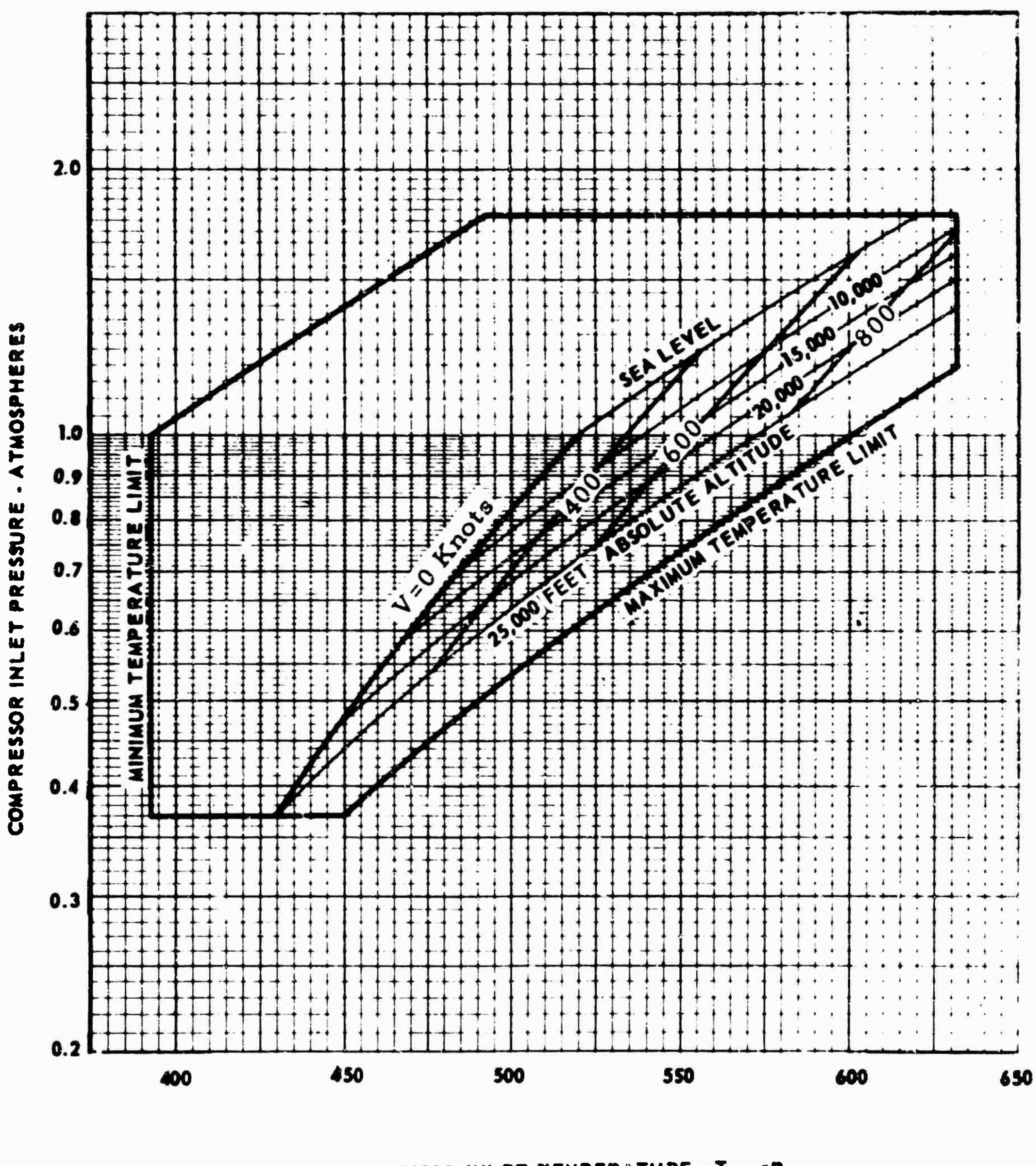


FIGURE 18

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED ENGINE STARTING AND OPERATION LIMITS

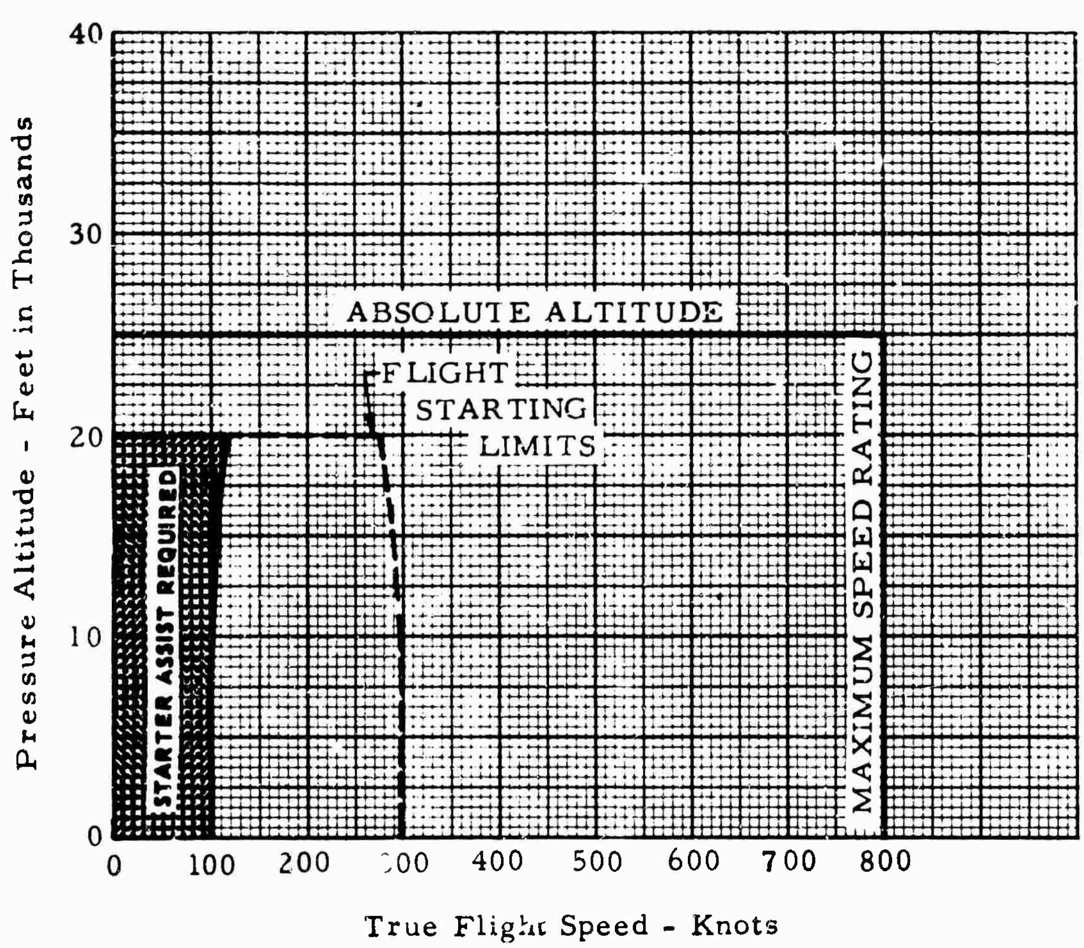


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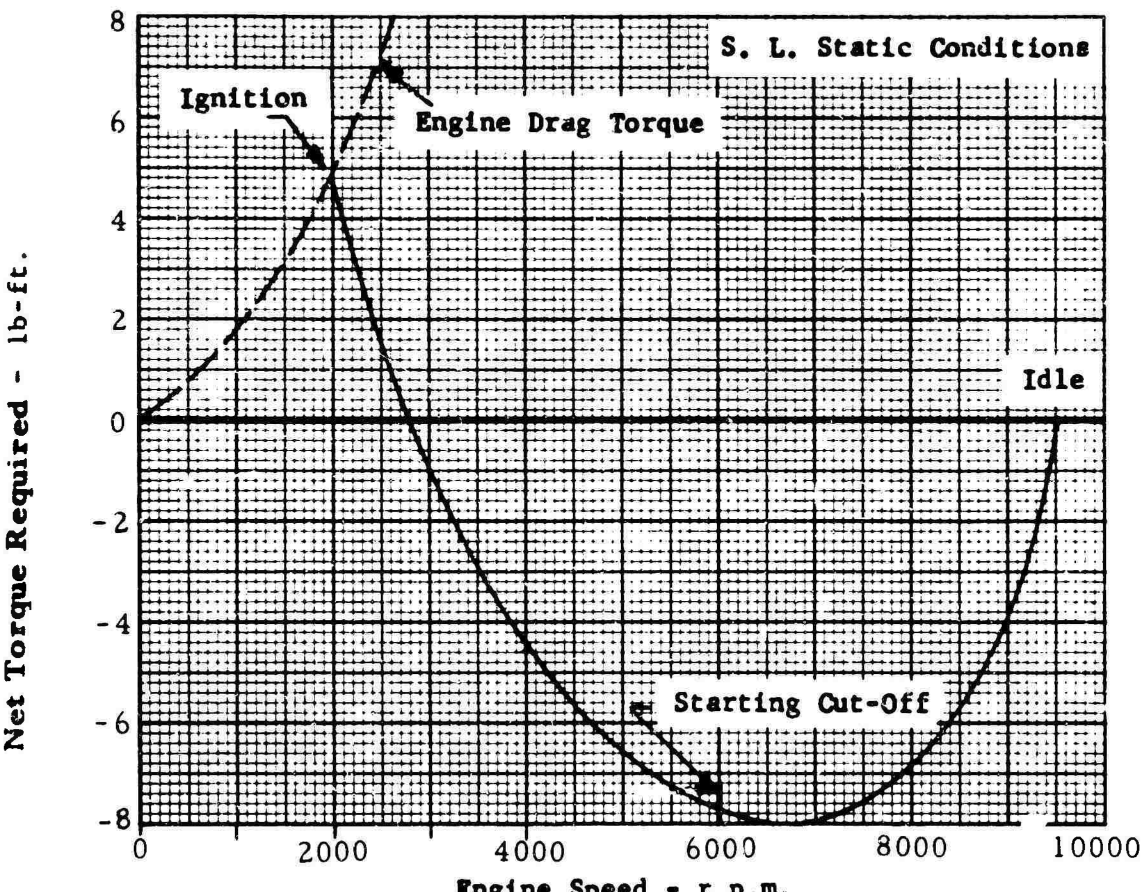
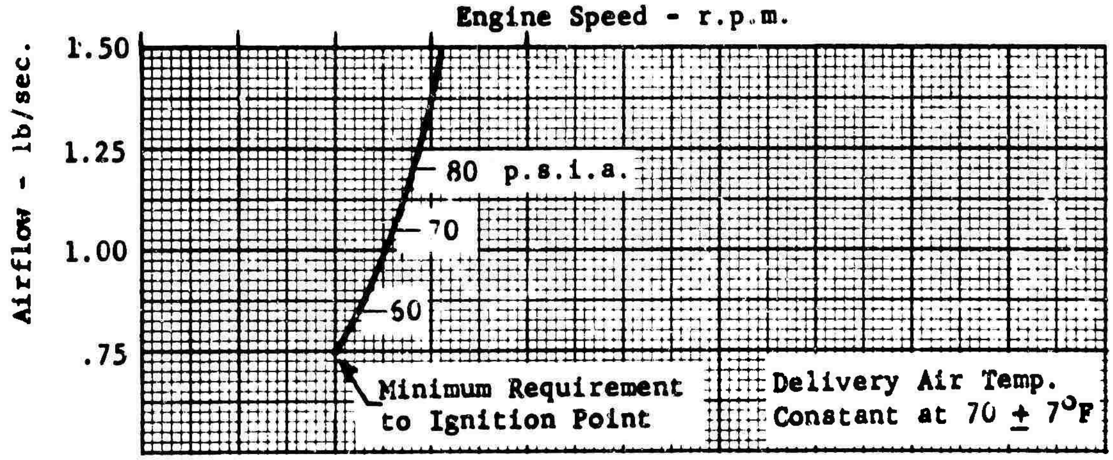
FIGURE 19

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED ENGINE STARTING REQUIREMENTS





ESTIMATED AIR IMPINGEMENT STARTING CHARACTERISTICS

FIGURE 20

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED
ENGINE WINDMILLING CHARACTERISTICS

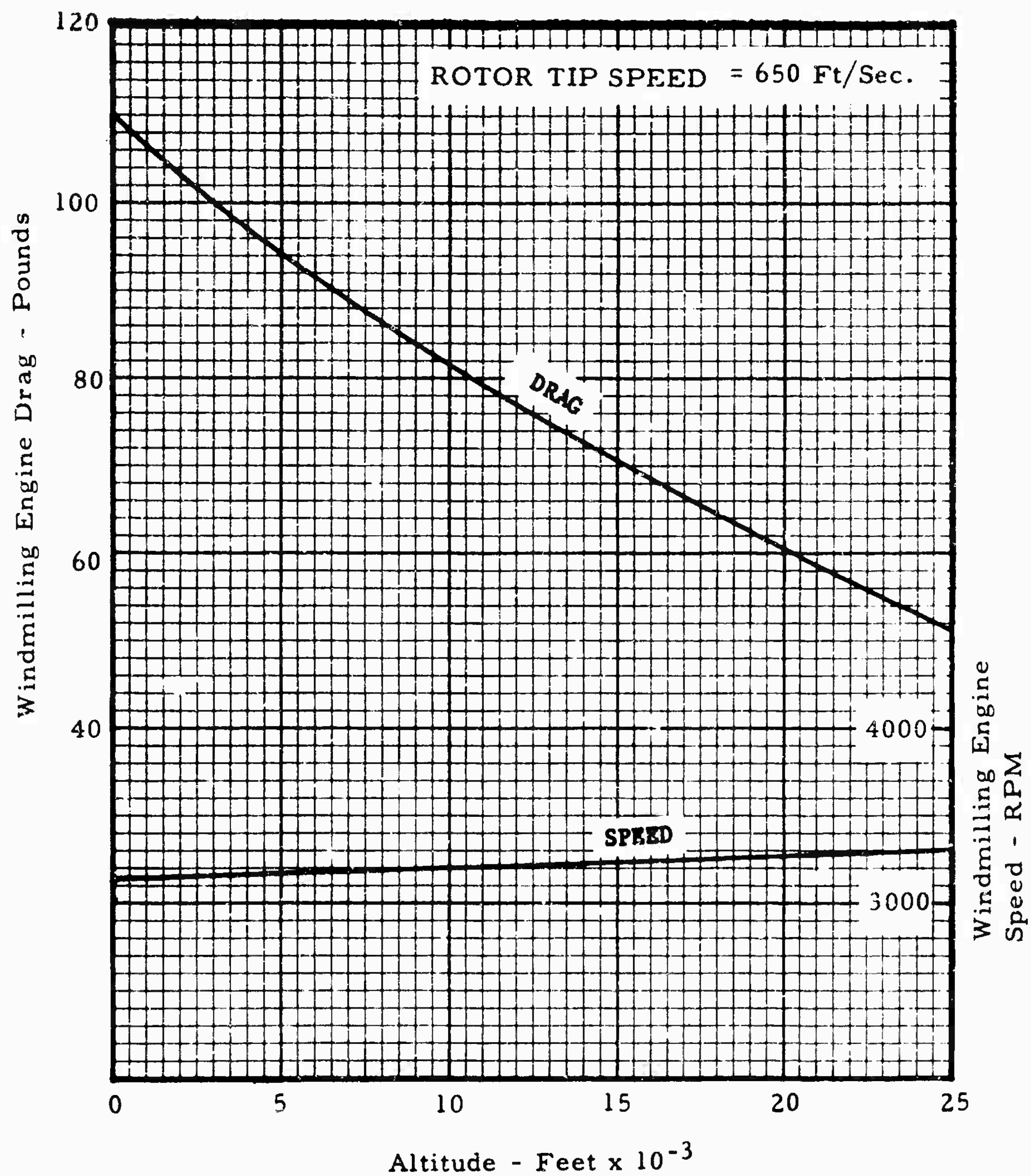


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FIGURE 21

CAE MODEL 357-1 TIP TURBOJET ENGINE

ESTIMATED HEAT REJECTION AND OIL FLOW
VERSUS ENGINE SPEED

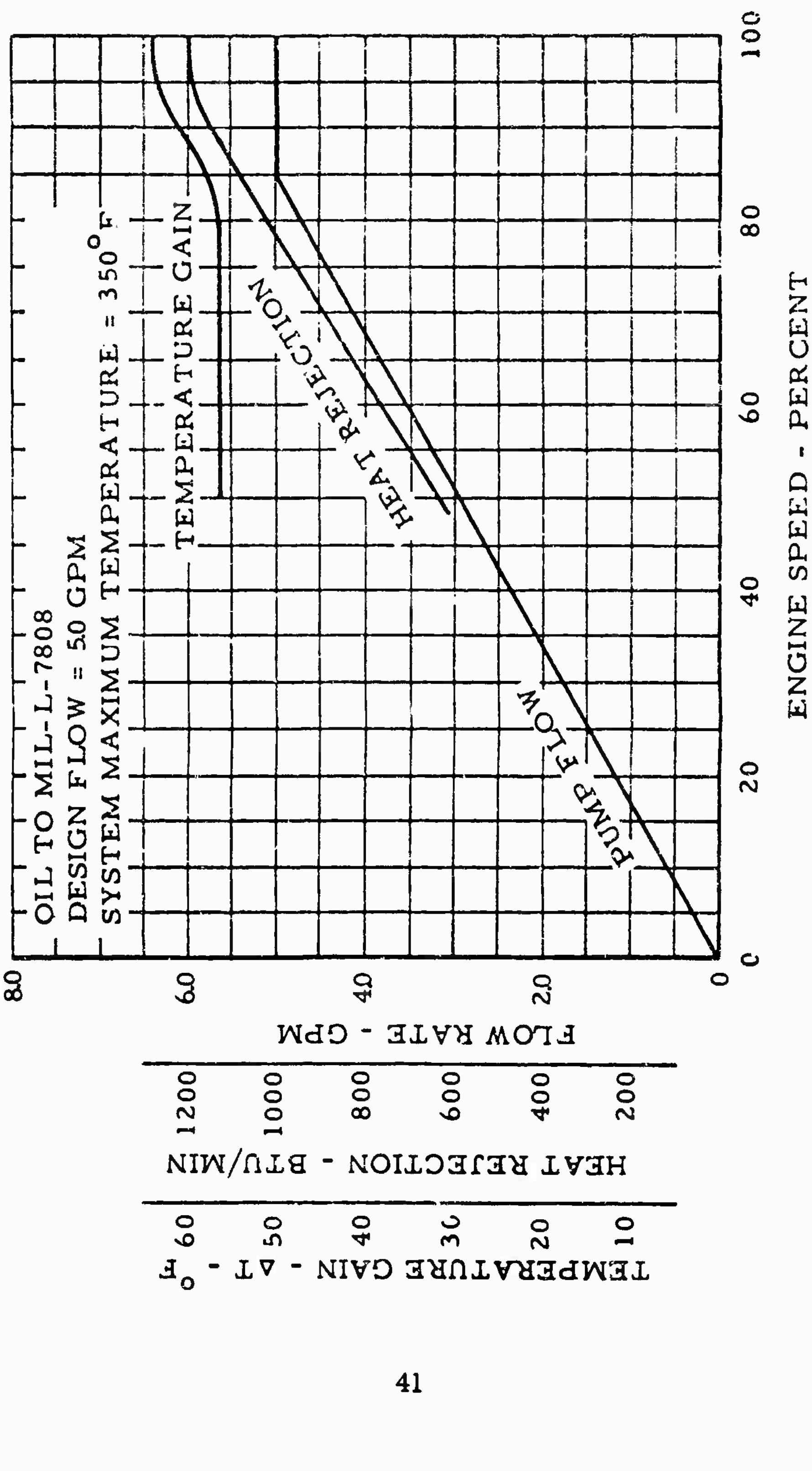

FIGURE 22

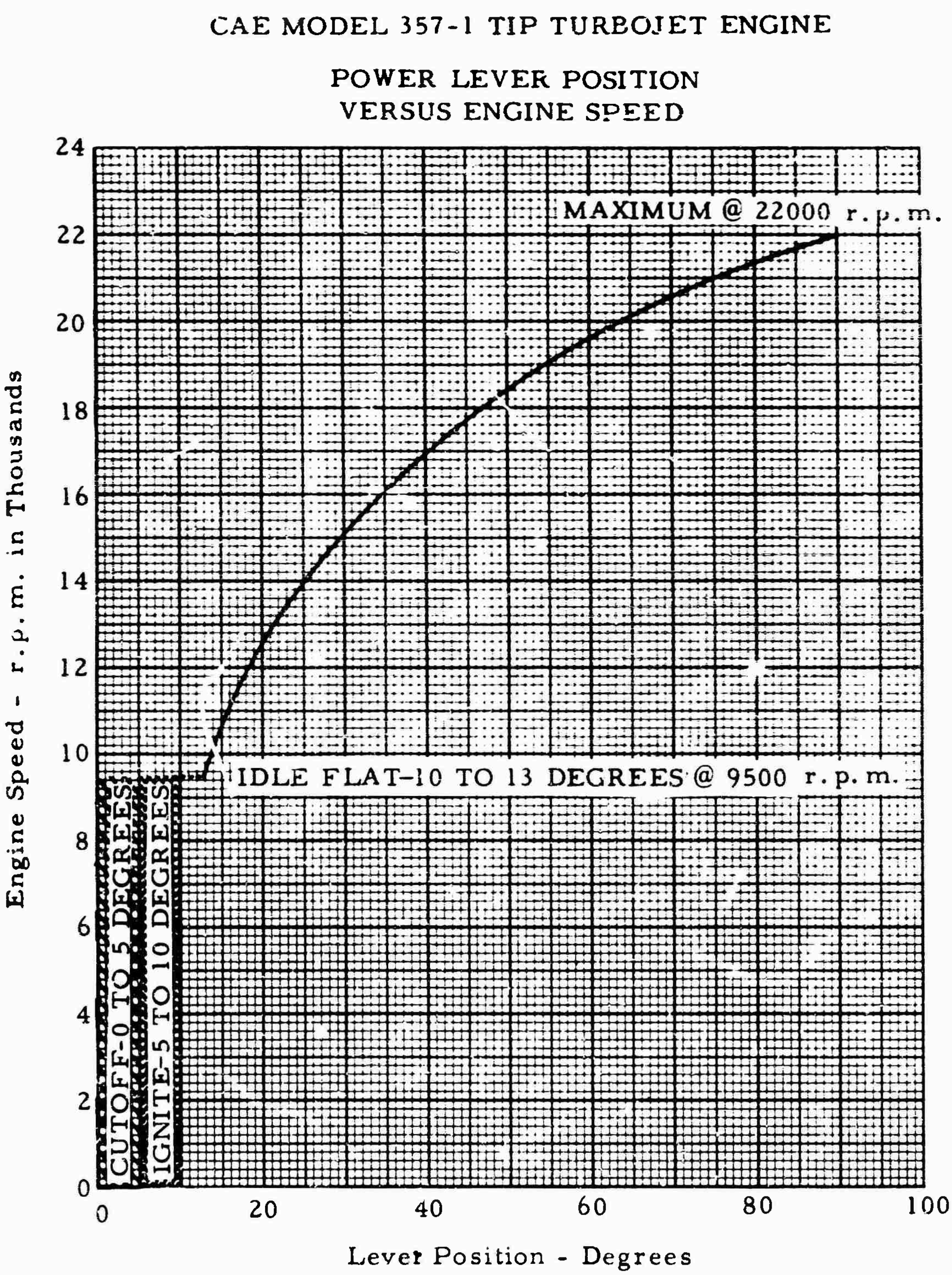
CAE MODEL 357-1 TIP TURBOJET ENGINE
POWER LEVER POSITION
VERSUS ENGINE SPEED
MAXIMUM @ 22000 r.p.m.
IDLE FLAT-10 TO 13 DEGREES @ 9500 r.p.m.
CUTOFF-0 TO 5 DEGREES
IGNITE-5 TO 10 DEGREES
Engine Speed - r.p.m. in Thousands
0
2
4
6
8
10
12
14
16
18
20
22
24
0
20
40
60
80
100
Lever Position - Degrees

FIGURE 23

CAE MODEL 357-1 TIP TURBOJET ENGINE

ENGINE SPEED SENSING OUTPUT SIGNAL

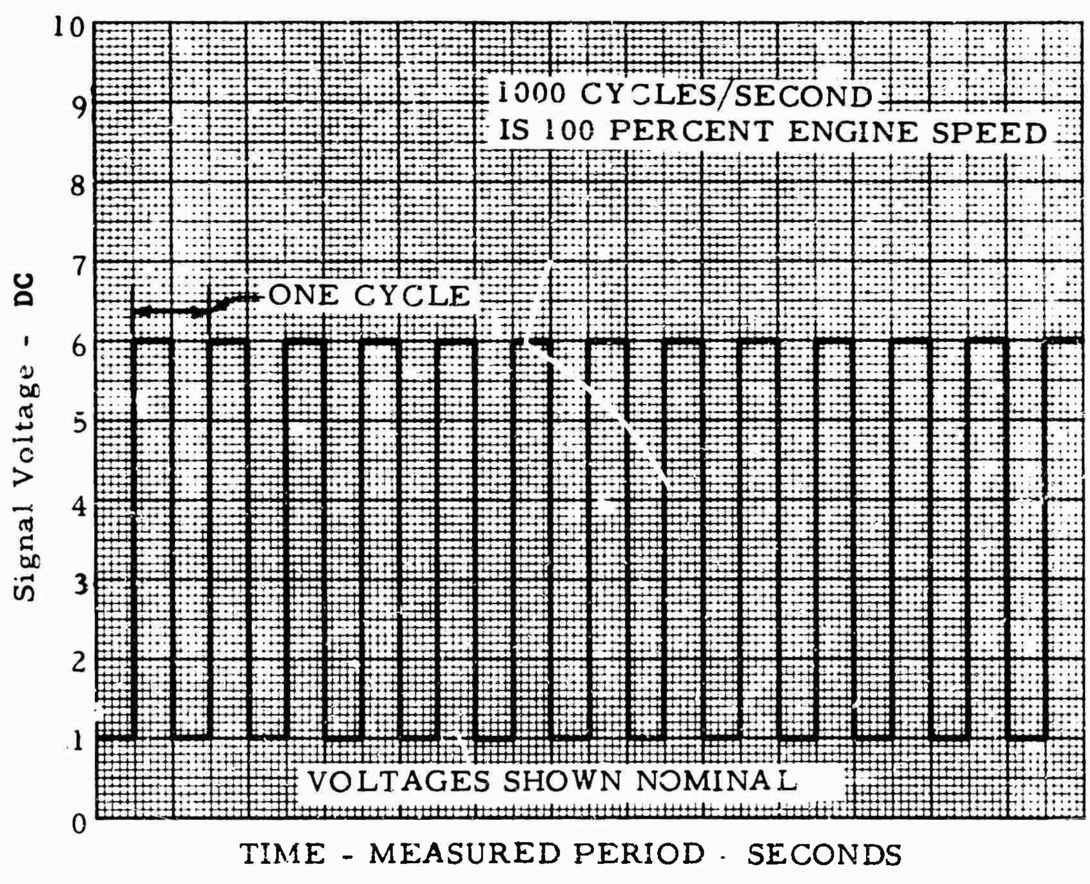

FIGURE 24

CAE MODEL 357-1 TIP TURBOJET ENGINE

JET WAKE DIAGRAM
MAXIMUM THRUST CONDITION

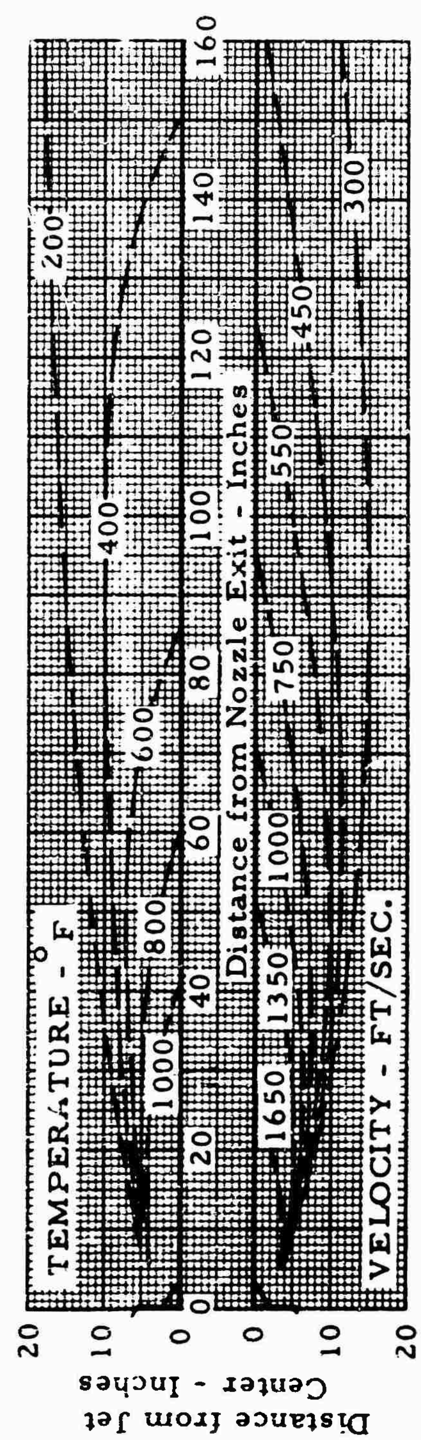

FIGURE 25

CAE MODEL 357-1 TIP TURBOJET ENGINE
ELECTRICAL SYSTEM DIAGRAM

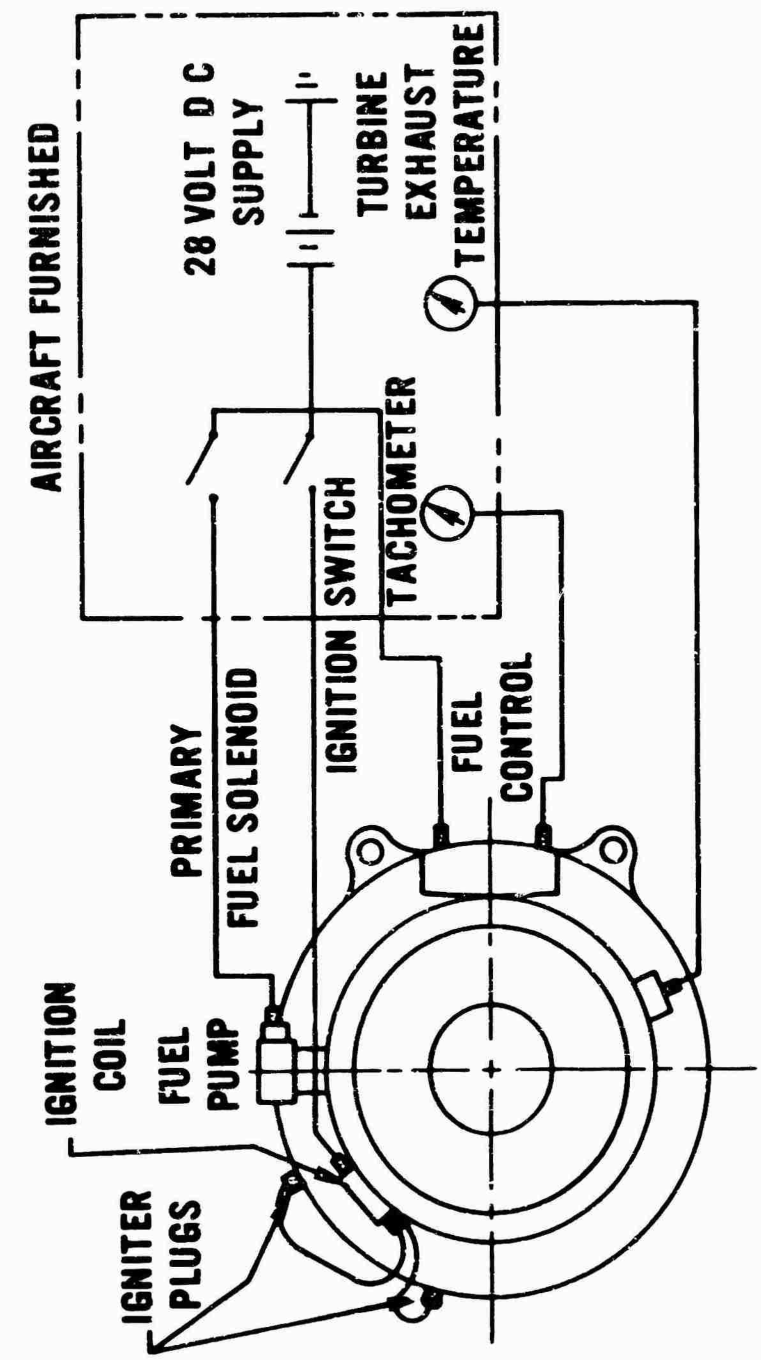

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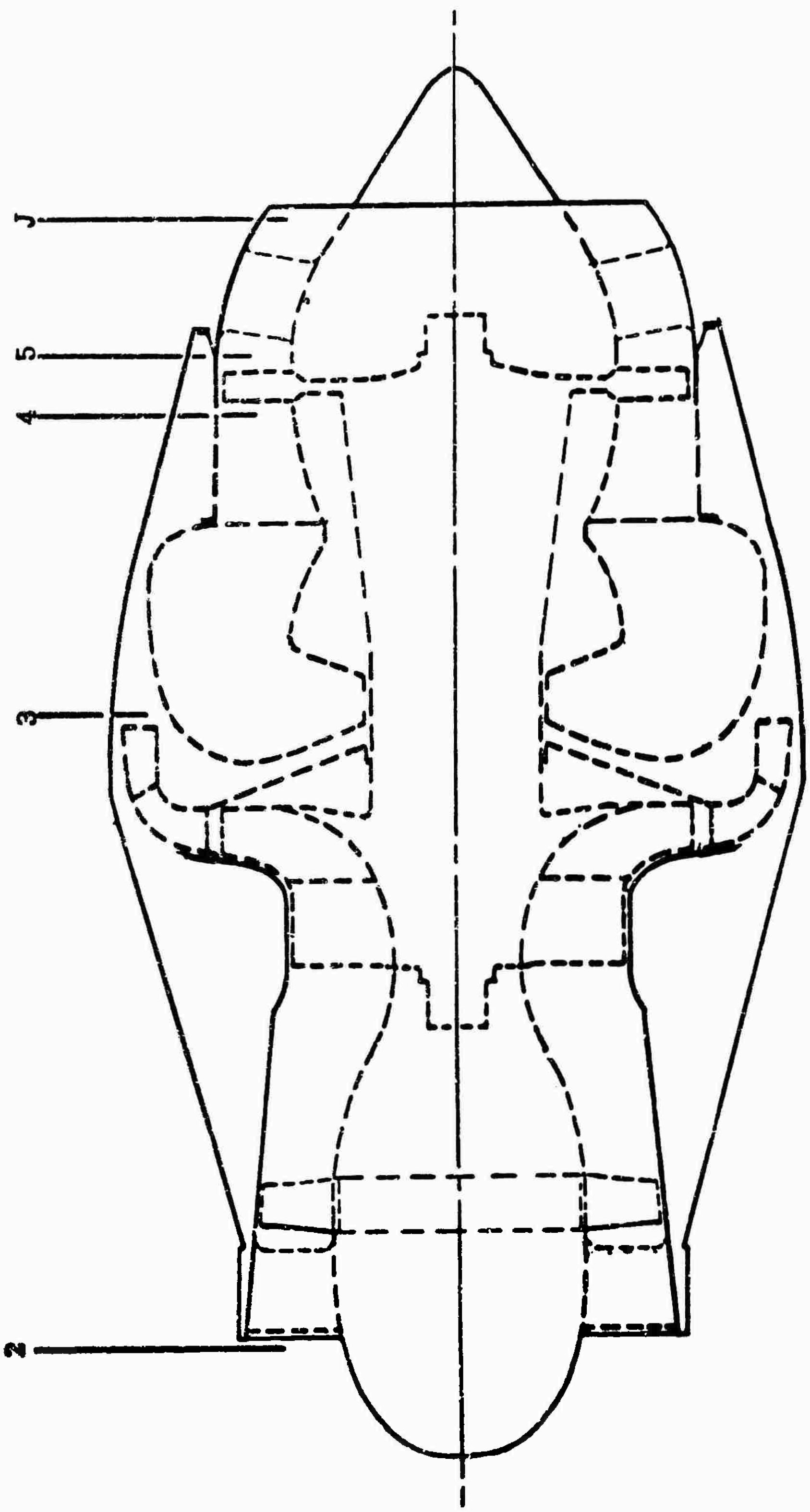
FIGURE 26

CAE MODEL 357-1 TIP TURBOJET ENGINE

GAS FLOW DIAGRAM AND IDENTIFICATION OF STATIONS USED IN PERFORMANCE ANALYSIS



2. Compressor Inlet

3. Compressor Outlet

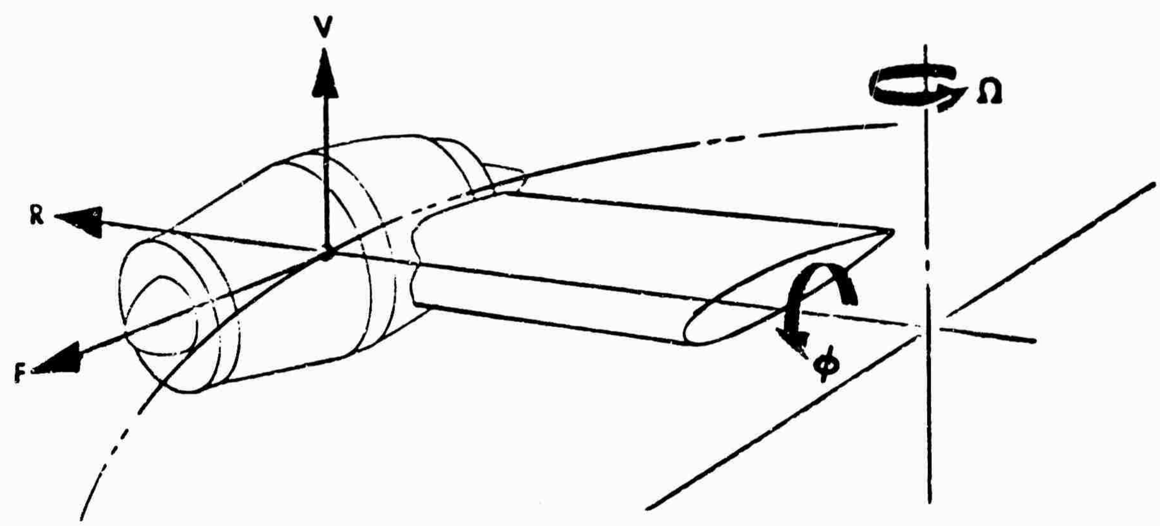
4. Turbine Inlet

5. Turbine Outlet

J Exhaust Gas Outlet

FIGURE 27

ENGINE LOAD DIRECTIONS
(As Listed in Table 3)



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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)	
5. AUTHOR(S) (Last name, first name, initial)	

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13. ABSTRACT

Volume XIII of a report entitled "Heavy-Lift Tip Turbojet Rotor System" contains Continental Preliminary Model Specification No. 2253-A, which contains requirement, capability, and engine performance data on the Continental Model 357-1 (1700-pound thrust) turbojet engine for helicopter rotor-tip mounting.

Unclassified
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Specification						
Helicopter Rotor Tip-Mounted Turbojet Engine						

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